

NASA Technical Memorandum 87569

NASA INFORMATION SCIENCES AND HUMAN FACTORS PROGRAM

ANNUAL REPORT, 1984

MAY 1985

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NASA

Automation and
Computer Sciences

Communication
Systems

Controls and
Guidance-Aeronautics

Controls and
Guidance-Space

Data Systems

Human Factors -
Aeronautics

Human Factors -

Sensor Technology

NASA Technical Memorandum 87569

**NASA INFORMATION
SCIENCES AND HUMAN
FACTORS PROGRAM**

ANNUAL REPORT, 1984

PREPARED BY

**NASA Office of Aeronautics and
Space Technology**

**Information Sciences and
Human Factors Division**



**National Aeronautics
and Space Administration**

**Scientific and Technical
Information Branch**

1985

INTRODUCTION

The Information Sciences and Human Factors (IS&HF) Division is one of five divisions that comprise the Office of Aeronautics and Space Technology (OAST). This division sponsors research in both aeronautical and space technology; the Annual Report documents the most significant program accomplishments during the past year. Each year, the Annual Report is prepared to serve as the single mechanism for coordinating NASA activities with industry and industrial IR&D managers. This document is also intended to communicate significant technical accomplishments to NASA technologists and project engineers and to other government agencies and academia.

The IS&HF Program consists of six major elements: Automation and Computer Sciences, Communications Systems, Controls and Guidance, Data Systems, Human Factors, and Sensor Technology. Accomplishments are presented in all six categories; Controls and Guidance and Human Factors are shown in two sections, Space and Aeronautics. The program technical objectives, sub-elements, related NASA programs and potential applications are included in the appropriate section. Program funding during fiscal year 1984 was approximately the same as in FY 85, which is shown below.

<u>ELEMENT</u>	<u>TOTAL R&D</u> <u>(\$K)</u>
AUTOMATION AND COMPUTER SCIENCES	37,500
COMMUNICATIONS SYSTEMS	7,048
CONTROLS AND GUIDANCE	29,100
DATA SYSTEMS	8,017
HUMAN FACTORS	24,000
SENSOR TECHNOLOGY	6,795

To aid in the communication of program efforts, the names and phone numbers of Headquarters' program managers are included in this report along with the names and phone numbers of the key Center technologists who conducted or managed the significant technology activities.

DIVISION DIRECTOR: Lee Holcomb
(202) 453-2785

DEPUTY DIRECTOR: Duncan McIver
(202) 453-2782

NASA DIRECTORY

<u>Center</u>	<u>Symbol</u>
Ames Research Center Moffet Field, CA 94035	ARC
Ames Research Center Dryden Flight Research Facility P.O. Box 273 Edwards, CA 93523	DFRF
Goddard Space Flight Center Greenbelt, MD 20771	GSFC
Headquarters NASA/OAST/RC Washington, DC 20546	HQ
Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, CA 91109	JPL
Lyndon B. Johnson Space Center Houston, TX 77058	JSC
John F. Kennedy Space Center Kennedy Space Center, FL 32899	KSC
Langley Research Center Hampton, VA 23665	LaRC
Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135	LeRC

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AUTOMATION AND COMPUTER SCIENCES

The overall objective of the Automation and Computer Sciences Technology Program is to provide the technology for space systems to automatically perform functions heretofore requiring human reasoning, expertise and manipulative skills and to adapt computing technology to aerospace applications. Major sub-elements include automated fault management, expert systems and teleoperator and robotics technology as well as fundamental computer science research. Support for Class VI computers is also included to provide aerospace researchers access to the most modern developing computer systems.

Related NASA programs include advanced data systems projects of the Office of Space Tracking and Data Systems and the advanced development program of the Office of Space Transportation Systems. Potential uses include science and applications missions, space platform or space station, space shuttle and commercial satellite applications.

PROGRAM MANAGER: Dr. Ronald Larsen
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KAOS--AN AUTOMATED AIRBORNE ASTRONOMICAL FLIGHT PLANNING TOOL

The Kuiper Airborne Observatory Scheduler (KAOS), a knowledge-based expert system, has been developed under the auspices of the Information Sciences Office at NASA Ames Research Center. The application of this computer program is to generate flight plans for airborne astronomical observations. Observations are scheduled for the Kuiper Airborne Observatory at Ames.

The input to KAOS is a list of objects and viewing duration. From this input, KAOS generates a flight plan that satisfies the imposed restrictions. The rule base of KAOS is capable of generating plans that incorporate the following features: objects are in the telescope elevation range (35-70°); overflight of restricted and warning zones is avoided; and, at the termination of the observations, the aircraft can reach its destination in the remaining flight time. The knowledge base consists of the objects' coordinates and the location of the restricted and warning zones. Two modes of operation are available to generate flight plans: automatic and interactive.

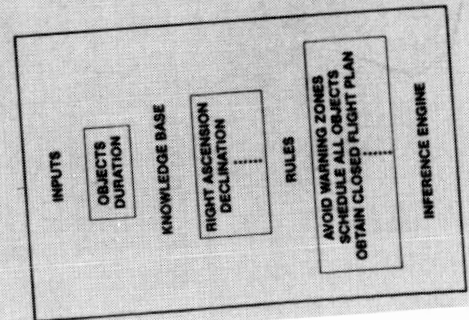
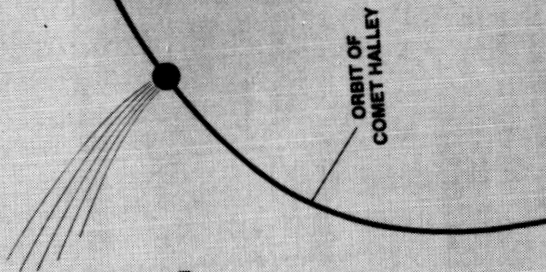
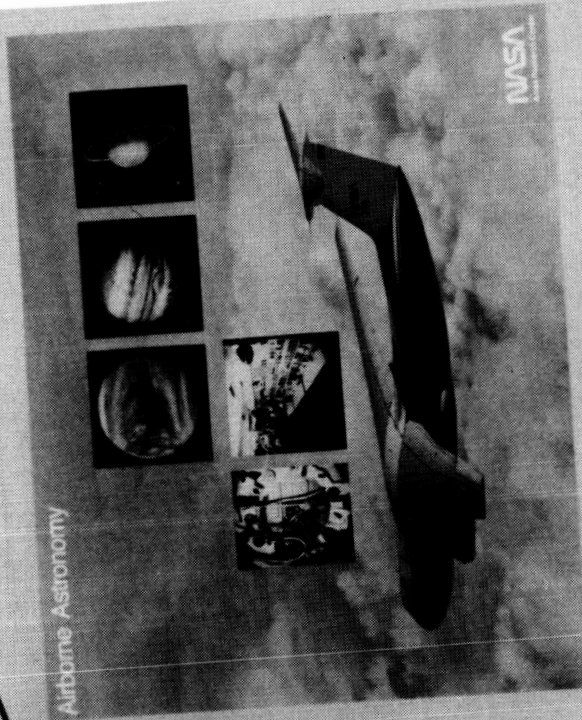
The advantages of using KAOS are that throughput utilizing KAOS' computational capability exceeds the expert's performance and that a layman can develop flight plans. These factors reduce the demand on the expert's time. Even though KAOS has only recently been demonstrated (November 27, 1984), it has already been used to develop flight plans for U.C., Berkeley (November, 1984) and Cornell (December, 1984). KAOS is currently being utilized to optimize flight plans for Comet Halley Observations (1985-86).

TECHNICAL CONTACT: Philip R. Nachtsheim, ARC, (415) 694-6526

KUIPER AIRBORNE OBSERVATORY SCHEDULER (KAOS)

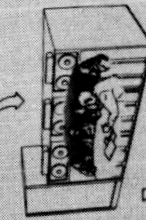
BENEFITS

- AUTOMATED ASTRONOMICAL FLIGHT PLANNING SYSTEM OPERATIONAL NOVEMBER 1984
- ENHANCED PRODUCTIVITY OF SCIENCE TEAM FOR REAL-TIME, INTERACTIVE, MISSION PLANNING AND SCIENCE OBSERVATIONS
- ENHANCED FLIGHT PLANNING FOR COMET HALLEY MISSION — 1985-86
- TRANSFERRABLE TO SIRTIF AND LDR

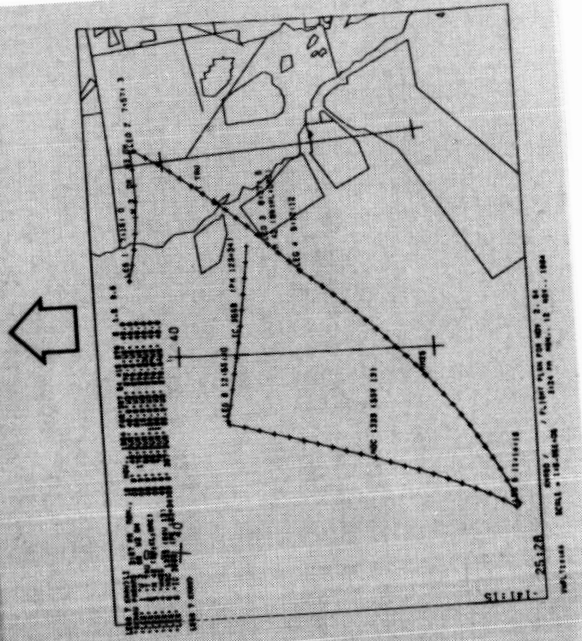


KAOS
"AN INTELLIGENT ASSISTANT"

DATA
KNOWLEDGE BASE
CONTROL



QUERIES
ADVICE



COMPLIANT ROBOTICS WITH FORCE FEEDBACK

The objective of this program is to advance robotics techniques to the extent that hardware can be efficiently and automatically assembled or serviced on ground or in orbit. The primary considerations relating to the robotics tasks are that (1) the hardware is highly complex, (2) there are precision components having small clearances, and (3) the hardware is either a unique custom item or is available only in small quantities.

The complexity and limited production volume of most NASA hardware translates into a requirement for a very large set of automatically generated robot motions as needed for assembly or service. Working with small clearances requires that the robot have an advanced form of force feedback to position components accurately. To meet these requirements, the Intelligent End Effector (IEE), a robot equipped with compliance and force feedback for precision assembly, and knowledge engineering and robot control software techniques have been combined with an existing Computer-Aided Design (CAD) facility.

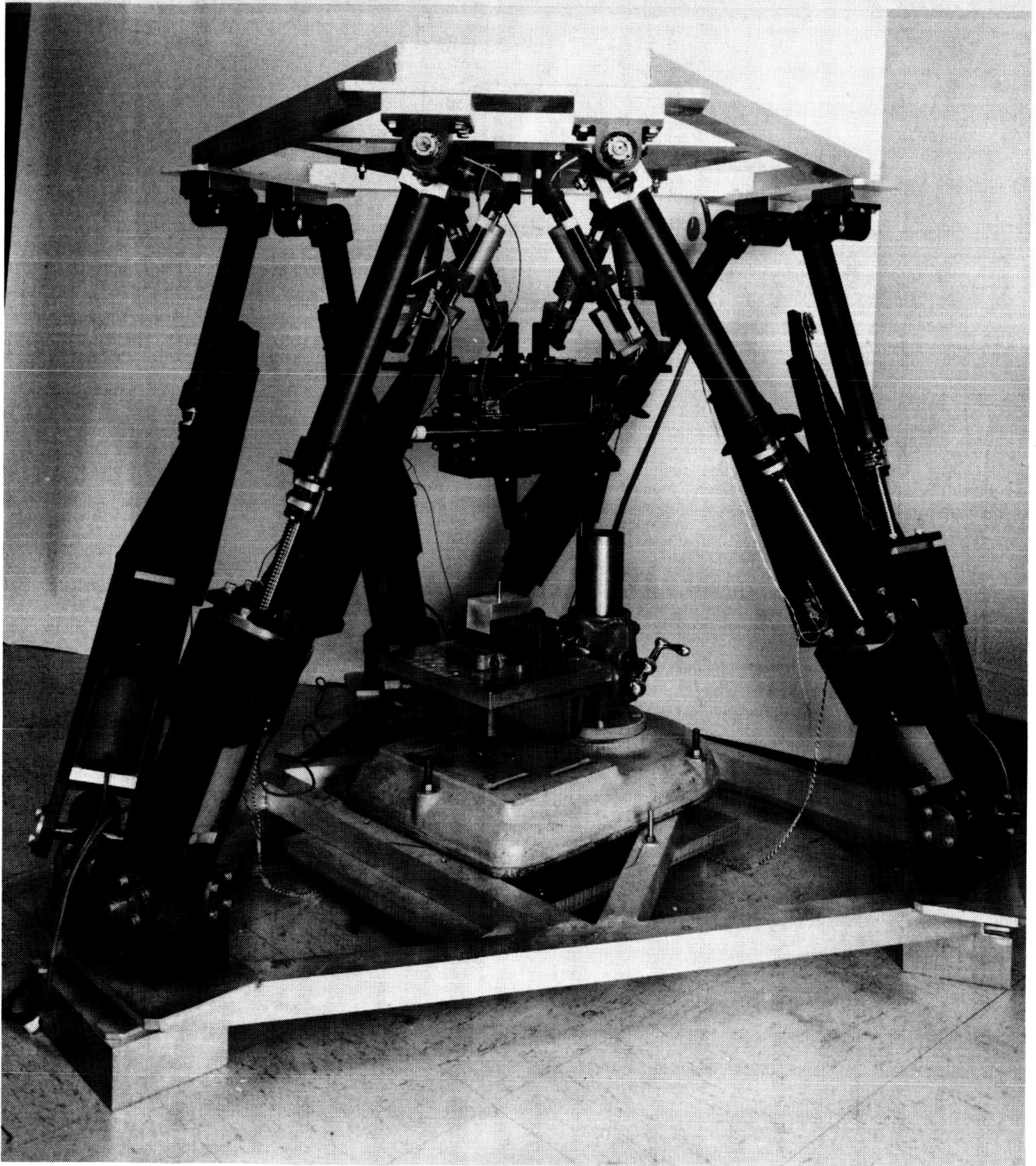
The IEE, with its compliance, force feedback, and six-degree-of-freedom capabilities, has been built and has proven to be functional for its intended purpose. A significant body of software has been developed for controlling the IEE, for positioning the movable platforms and for reading and interpreting its force-feedback sensors. In addition, software has been provided for future enhancements to the robot, including controlling programs for a gripper and a wrist mechanism. A model program was written to demonstrate and test significant features of the system, including knowledge acquisition, use of heuristics like part visibility and bolt hole position, dynamic databases, and recursive search.

Future work on automated assembly system will focus on two principal areas: the completion of the Automated Sequence Planner (ASP) program, and an expansion of the robot control software, with the inclusion of artificial intelligence techniques.

TECHNICAL CONTACT: Lloyd Purves, GSFC, (301) 344-5837

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COMPLIANT ROBOT WITH FORCE FEEDBACK



SENSOR BASED CONTROL OF A ROBOT ARM

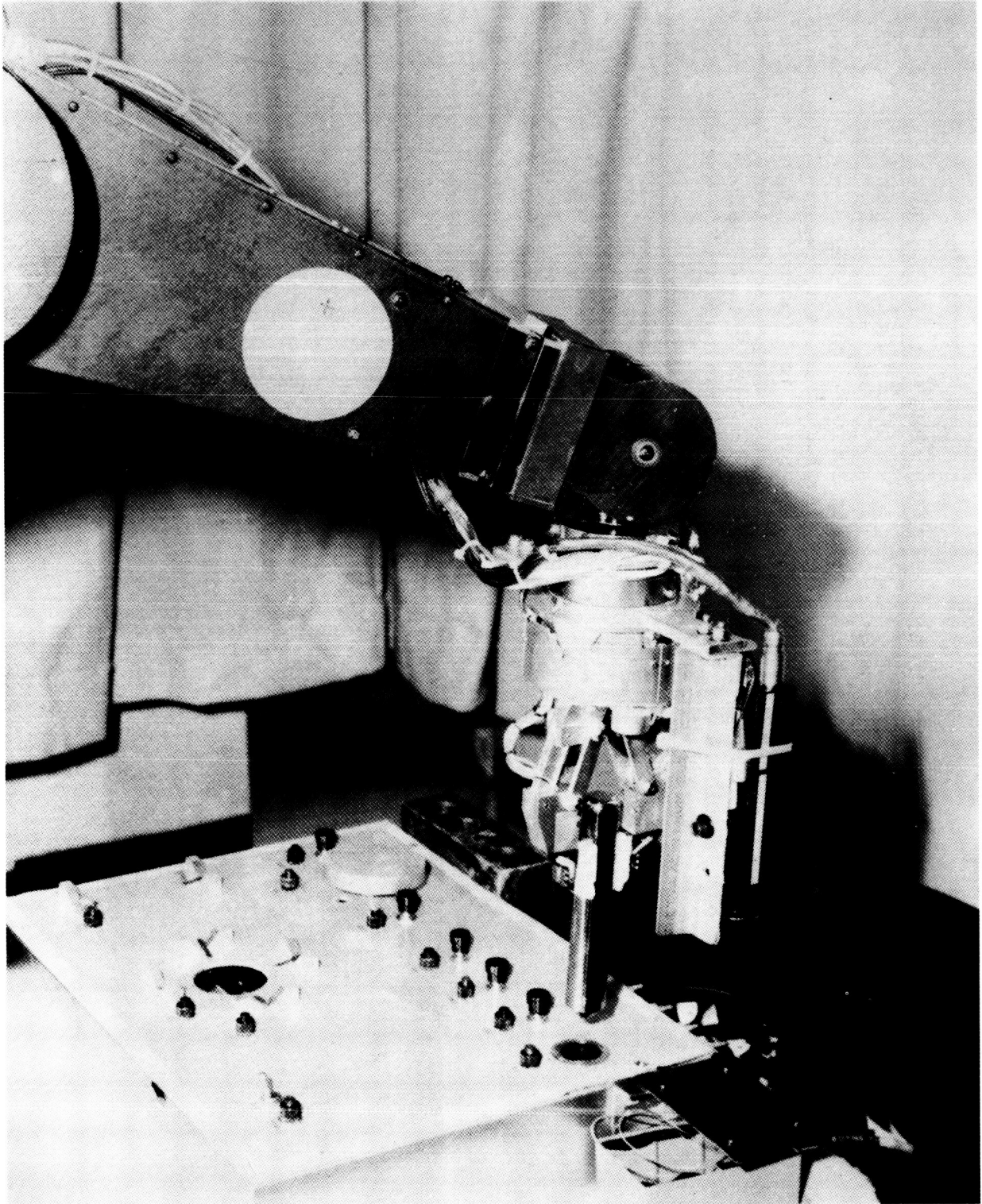
Langley Research Center is investigating manipulator control based on integrated sensor systems. The research testbed is structured such that varying combinations of sensors and sensor systems can be incorporated in the manipulator system. The effectiveness of the human as a sensor system has been investigated in a series of experiments involving a human operator with both a direct view of the target and with a machine aided (TV link) view of the target. The results of these experiments serve to establish relationships to previous research in this area and also to provide comparison data for studies involving manipulator control that is based solely on machine sensing.

The Automation Technology Branch at LaRC is currently investigating and refining techniques that demonstrate sensor-based closed loop control using vision feedback for target location in 3-space and with force/torque feedback for tool application at the target. Two tasks are currently being attempted to demonstrate the control function--the insertion of a peg in a hole and the tightening/loosening of bolts securing a model of a biocontainer used on the LDEF satellite. Peg-in-the-hole insertion has been accomplished, and completion of the securing bolt demonstration is a function of further refinement of active compliance techniques.

The three dimensional orientation and location of the target is determined using methods based on the perspective transformation. Target position is presently determined by the detection of four infrared LEDs arranged in a rectangle on the target. Any four marks can be used, but the use of the LEDs lessens the image processing load. Vision sensing is being expanded so that the target can be located using any four or more identifiable points arranged in any reasonably convex shape. The introduction of a new technique (the result of a parallel effort) will allow the use of an attribute augmented geometric model to derive the required points. Upon contact of the tool with the target, force/torque sensors provide data that modify the amount and direction of applied force. In the peg-in-the-hole task, forces and torques resulting from the peg's contact with the walls of the hole are nulled to facilitate insertion and withdrawal. This technique will be operational in 1986.

The photograph shows the hardware involved in the demonstration. The vision sensor is a solid state camera mounted at the manipulator's wrist. The target is a cylindrical hole located on a taskboard that contains other plausible targets such as pushbutton and toggle switches. The sensor detects four LEDs mounted on a pad located at the upper right hand corner of the taskboard and transmits their image to an image processor. The processor in turn transmits the target location, derived from the image, to the arm controller. Force/torque sensors in the fingers and at the wrist of the manipulator inform the arm controller of the force vectors resulting from the peg's contact with the target. The controller processes all sensor data and derives manipulator joint angle commands necessary to move the peg to the hole and insert it.

SENSOR BASED CONTROL OF A ROBOT ARM

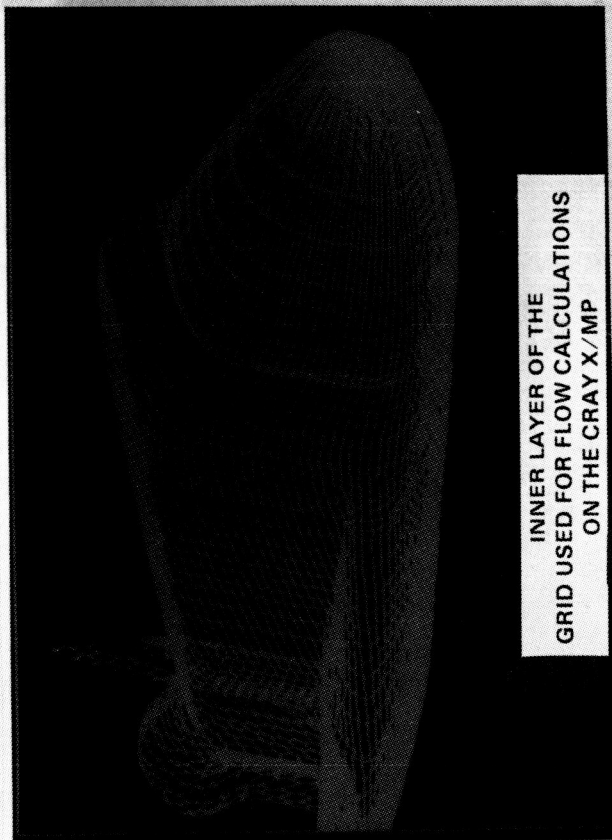


GRAPHICAL STUDY OF THE FLOW FIELD AROUND THE SPACE SHUTTLE

The purpose of this study was to investigate the flow about the space shuttle to determine if the flow could possibly dislodge ice which forms near the wing body interface, causing this ice to damage the heat shields on the main engines. The photo in the upper left corner (opposite page) is the body layer of the 70 x 45 x 40 computational grid. The upper right corner photo depicts the paths of particles released at four different grid lines. The graphics research and development involved is shown in the lower photo, which shows the particle paths superimposed on a shaded representation of the shuttle surface.

The combination of the stream lines and surface representation and the fact that the entire image could be zoomed or rotated dynamically on a Silicon Graphics IRIS workstation permits researchers to better understand the flow field and any possible interaction with ice formation. Future work will include developing techniques for displaying three-dimensional contours as translucent surfaces or combinations of contours and stream lines to better represent flow field characteristics for researchers.

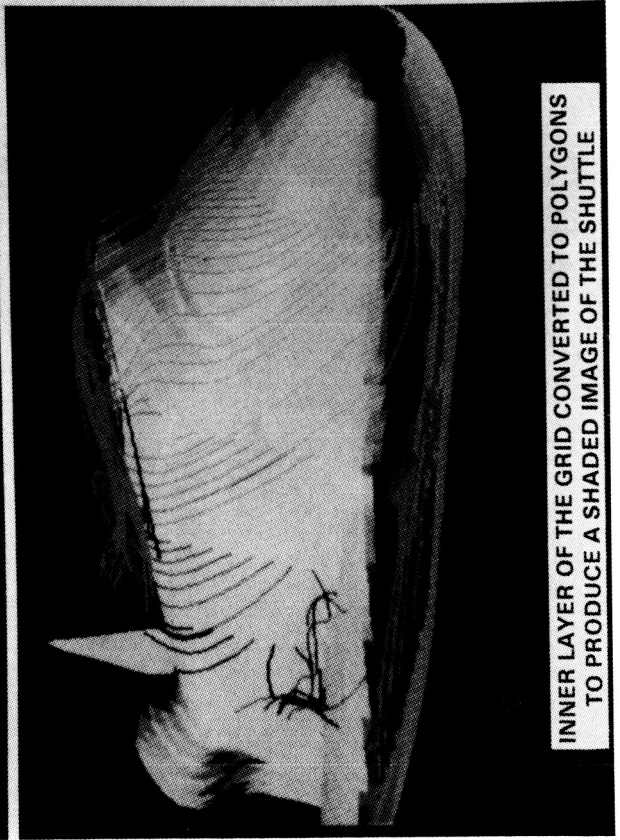
SIMULATION OF FLOW AROUND THE SHUTTLE



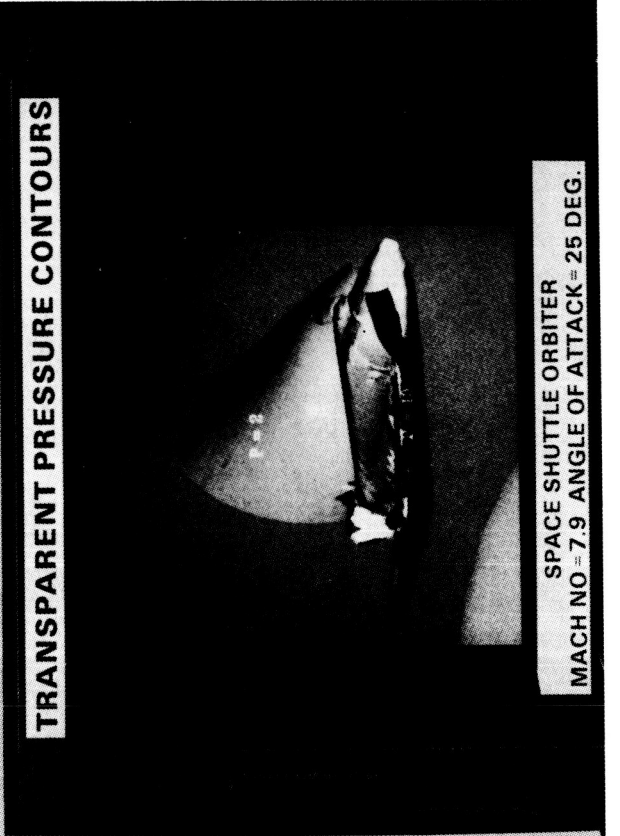
INNER LAYER OF THE
GRID USED FOR FLOW CALCULATIONS
ON THE CRAY X/MP



STREAMLINES COMPUTED BY PLOT3D IN
GRAFIX FORMAT ON A VAX 11/780



INNER LAYER OF THE GRID CONVERTED TO POLYGONS
TO PRODUCE A SHADED IMAGE OF THE SHUTTLE



TRANSPARENT PRESSURE CONTOURS

SPACE SHUTTLE ORBITER
MACH NO = 7.9 ANGLE OF ATTACK = 25 DEG.

SURFACE REPRESENTATION OF WIND TUNNEL DATA FOR THE OBLIQUE WING

This project was designed to demonstrate the feasibility of presenting experimental data in the same way as computational aerodynamics data. Should this be successful, it may be possible to conduct computational and experimental tests at the same time in hopes of increasing the productivity of aerodynamics researchers. The photo on the left (opposite page) indicates the pressure taps on an oblique wing wind tunnel model and their pressure values. The right photo indicates the continuous contours which can be generated using new mathematical techniques for utilizing sparse randomly spaced data.

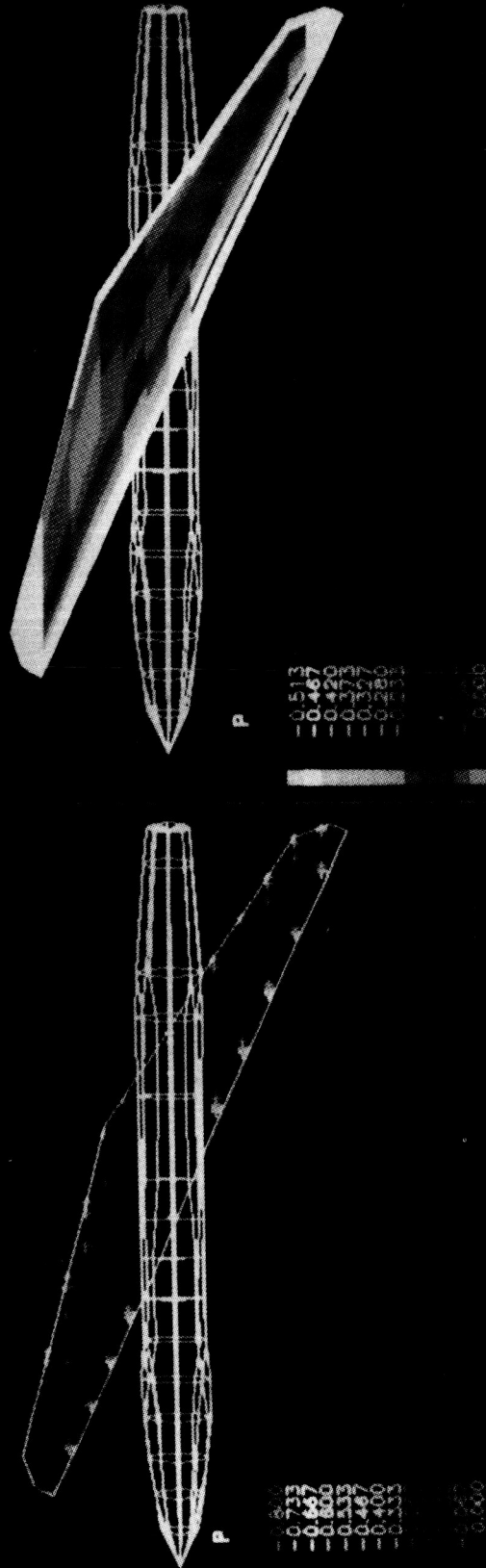
The photos shown are comparable to the presentation of computational data which comes from dense uniform computational meshes. This procedures demonstrates the feasibility of combining the use of computational and experimental aerodynamics via the use of common graphics presentation techniques.

TECHNICAL CONTACT: Kenneth G. Stevens, Jr., ARC, (415) 694-5949

Oblique Wing Design Project

Mach no. = 0.9 ; 65 deg. Yaw

4.4 deg. angle of attack



Contours using Data at Upper Taps

OPTICAL INFORMATION PROCESSING

A technological bottleneck in the field of optical information processing has been the lack of a programmable mask. The mask is required to produce spatial patterns suitable for modifying optically produced images. Mathematical transformations of the image are then possible in a truly optical manner, i.e., without an electronic computer. The objective of this program is to demonstrate that a programmable mask can be effected by suitable implementation of a liquid crystal display (LCD).

ARC has developed a LCD as a programmable mask (LCDPM), and has successfully demonstrated its capability to perform mathematical operations. The LCDPM has been used as a Hadamard Image Encoder; a reconstructed encoded image is shown in the accompanying figure. The comparison of input and output images is considered to be favorable, although the subtle details cannot be seen on the printed page.

Future program plans include using a similar mask incorporated into a matrix-matrix multiplier for a fast 32-bit processor.

TECHNICAL CONTACT: David Ennis, ARC, (415) 694-6525

OPTICAL INFORMATION PROCESSING

BENEFITS:

- SUCCESSFUL DEMONSTRATION OF PROGRAMMABLE MASK TECHNOLOGY CRITICAL TO OIP APPLICATIONS
- REALIZATION OF PARALLEL COMPUTING POTENTIAL CHARACTERISTIC OF OPTICAL INFORMATION PROCESSING

APPLICATION:

- OPTICAL PROCESSOR CONTROL OF SPACE STATION AUTOMATION INSTRUMENTATION

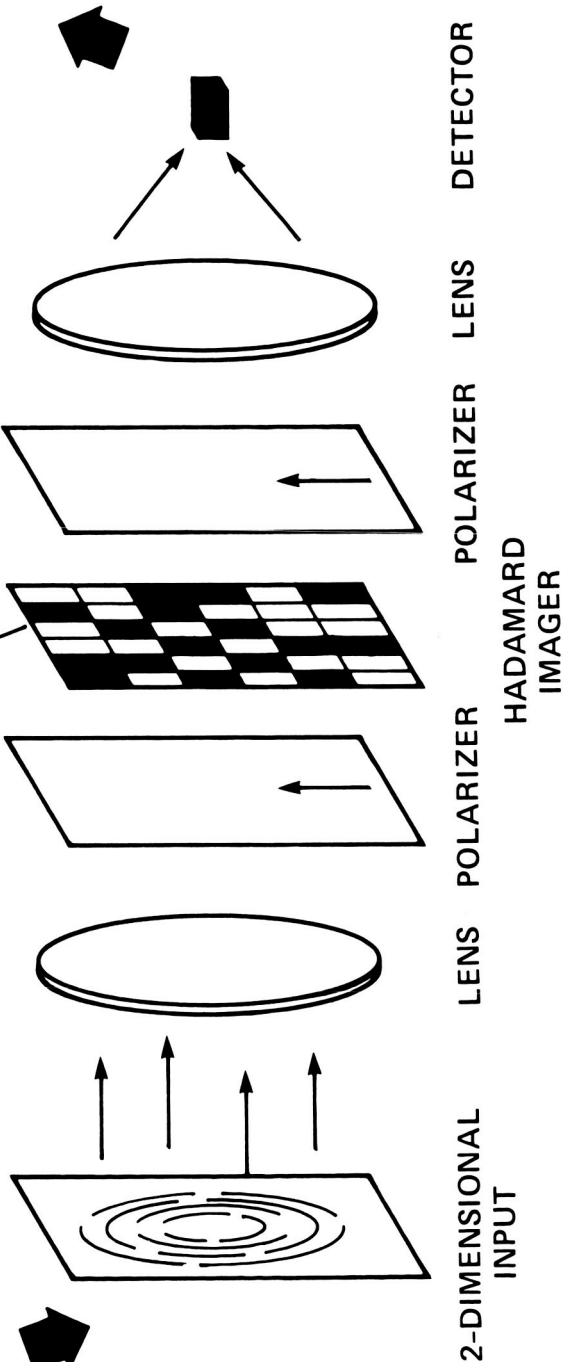


INPUT:
COHERENT LIGHT
DIFFRACTION
PATTERN



OUTPUT:
TWO-DIMENSIONAL
ENCODED IMAGE OF
INPUT LIGHT
DISTRIBUTION

ORIGINAL PAGE IS
OF POOR QUALITY



DEVISER--AUTOMATED MISSION PLANNING TOOL

An Automated Mission Planning Tool, called DEVISER, has been under development at the Jet Propulsion Laboratory. Its primary application at JPL is the planning and scheduling of science observations for unmanned spacecraft. The program objective is to improve DEVISER in terms of operating time and capability, leading to its utilization across a broader range of mission planning problems.

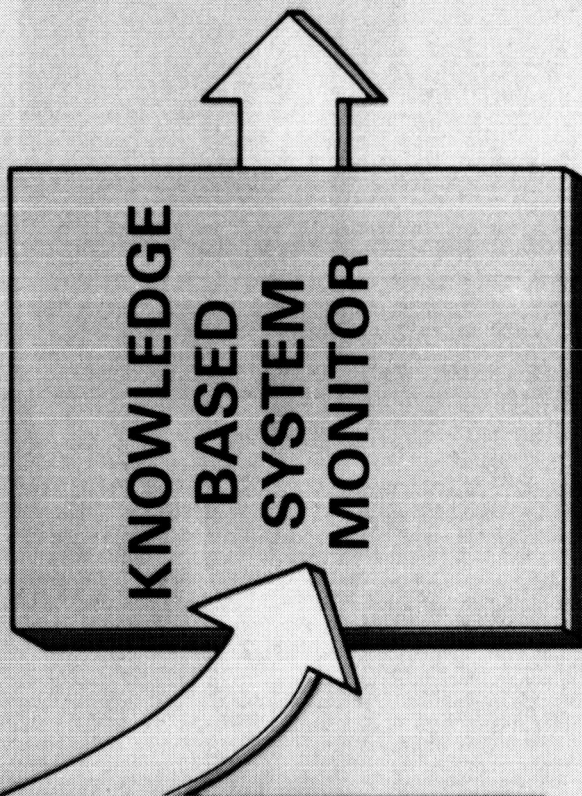
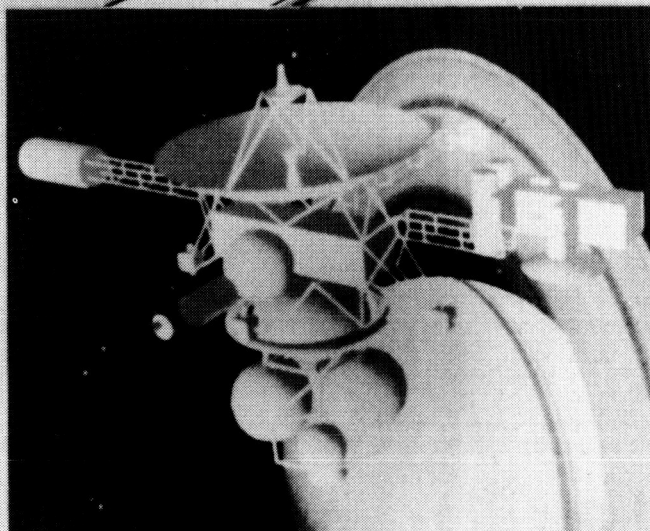
The basic DEVISER accepts input as a set of goals and a knowledge base of relevant actions, events and inferences. From these inputs, it automatically generates a parallel plan of activities to achieve the specified goals. Time is explicitly modeled.

The past year has seen a hundred-fold improvement in the execution time performance of the DEVISER mission planning system. Translation of DEVISER to the Symbolics 3600 and implementation of a new temporal scope of assertions mechanism accounted for the performance improvement. With these improvements, DEVISER now scales up successfully to real mission planning problems.

A recent improvement to DEVISER in FY 84 is a major new capability called activity splicing. Its purpose is to render the planner nearly insensitive to the order in which goals or subgoals are presented. Activity splicing permits activities to squeeze into the middle of a plan, for instance. The principal motivation for this new capability is to allow goals to be presented to the planner in order of decreasing priority, rather than in temporal order as was formerly required. The most important goals are, therefore, achieved first.

TECHNICAL CONTACT: Steven A. Vere, JPL, (818) 354-9280

AUTOMATED TELEMETRY MONITORING AND FAULT DIAGNOSTICS



- ALERT PERSONNEL
- IDENTIFY SOURCE OF FAULT

- VOYAGER DEMONSTRATION
JULY 1983
- UNDER EVALUATION FOR
SPACE STATION
APPLICATIONS

AUTOMATED SUBSYSTEMS MANAGEMENT

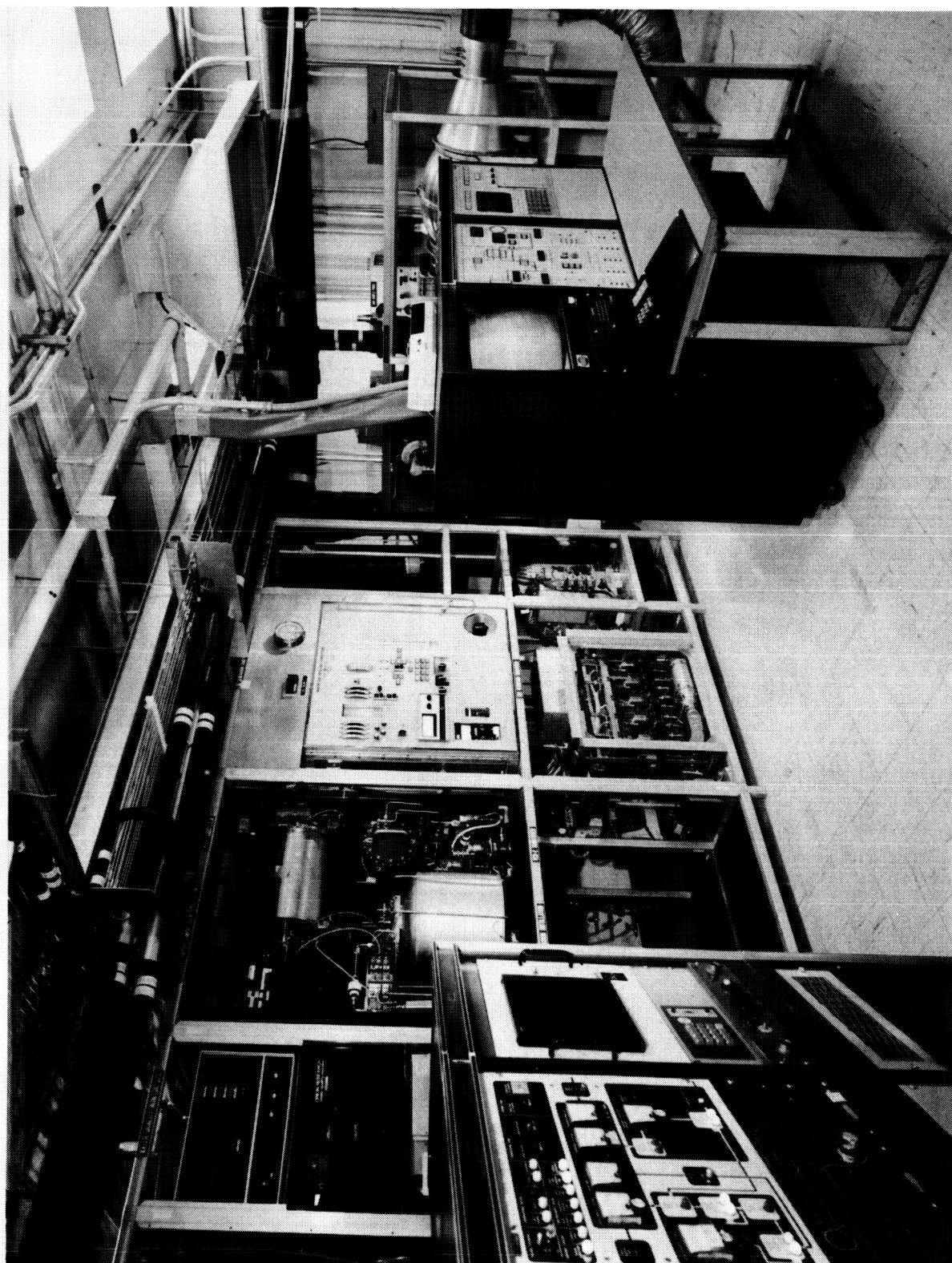
The objective of this program is to develop and demonstrate the feasibility of generic automation techniques for the control of spacecraft subsystems through the use of regenerative life support subsystems as a demonstration pilot system. The current system control approach for the environmental control and life support system (ECLSS) on the Space Shuttle Orbiter is very labor intensive for both flight and ground personnel. Long duration manned missions will require regenerative life support systems that are maintainable and repairable. The small crew size and mission demands for crew time will require near-autonomous command and control for spacecraft subsystems.

Study and analytical design of automated subsystems require that the following issues be addressed: automatic command and control, automatic trend monitoring, incipient failure detection, fault detection and isolation, allowable downtime, sparing and redundancy, on-board maintenance, instrumentation hierarchy, control hierarchy, software language, and local vs. central processing. The program approach is to conclude the study effort with a conceptual design of an automated ECLSS control, followed by an applications study, a preliminary design and a final design task. Fabrication and testing would follow, with demonstration testing occurring after acceptance of the subsystem hardware and software.

Completion of the applications study was on schedule, and the study report has been disseminated. The preliminary design effort is now in progress. Acceptance test hardware is scheduled to be delivered at the start of FY 86, with demonstration test completion scheduled for the end of CY 85.

TECHNICAL CONTACT: F. H. Samonski, JSC, (713) 483-4823

AUTOMATED ECLSS CONTROL



CRAY REPLACEMENT---CENTRAL COMPUTER FACILITY

The objective of this program is to provide selected NASA computer facilities with state-of-the-art computational hardware and software. Large, high speed processors are required to provide a capability for handling complex problems in internal aerodynamics, thermal and structural performance characteristics of propulsion system components, as well as to support fluid and flight dynamics programs.

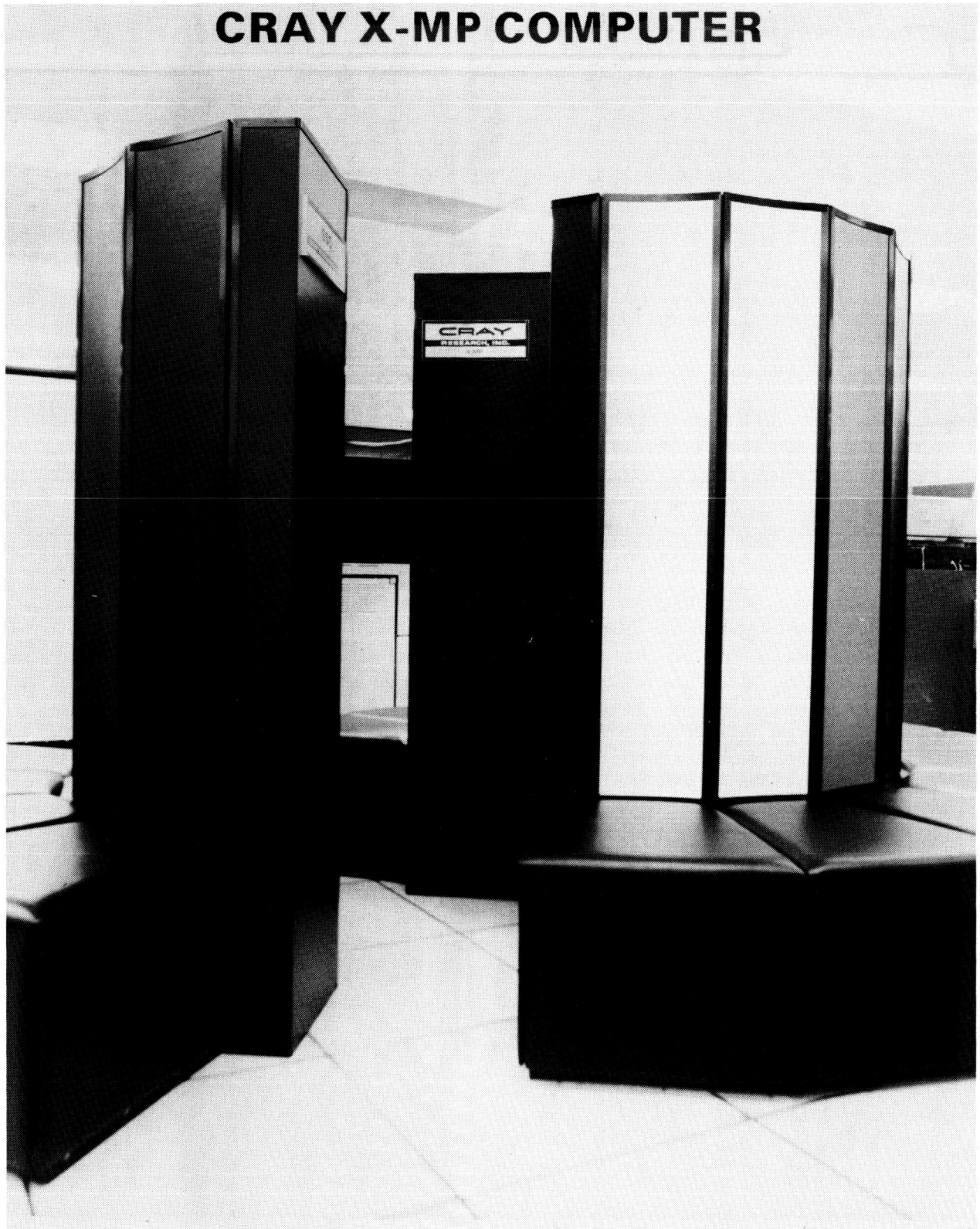
Computer facilities at ARC and LeRC have used the Cray 1-S to provide accelerated research progress; however, the Cray 1-S memory limitation, coupled with its imminent saturation, has limited this research. An upgraded High Speed Analytical Processor (Cray X-MP computer system) will be installed in the central computing facilities (replacing the existing Cray 1-S system), with the existing equipment providing the input and output for the system. The system, along with the available software and enhancements, will provide the improved capability for scientific computation (math modeling) that will ensure continued research preeminence.

Acquisition and installation of Cray X-MP computers at both ARC and LeRC has been completed. The systems are being leased for a three year period, after which system replacement is anticipated.

TECHNICAL CONTACT: P. L. Yohner, LeRC, (216) 433-4000, Ext. 361
C. E. Rhoades, Jr., ARC, (415) 694-5258

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CRAY X-MP COMPUTER



RIACS--RESEARCH INSTITUTE FOR ADVANCED COMPUTER SCIENCE

The Research Institute for Advanced Computer Science (RIACS) is located at the NASA Ames Research Center, Moffett Field, California. It is operated by the Universities of Space Research Association (USRA), a consortium of fifty-four universities, under a contract from the National Aeronautics and Space Administration (NASA). RIACS began operation on June 1, 1983.

The principal purpose of RIACS is to significantly strengthen computer science at the Ames Research Center by conducting basic research in areas relating to aerospace and by strengthening ties with the university and industry communities. This purpose will be carried out by a coordinated program of research supported by contracts from NASA and other agencies (core research) and by joint projects with research groups at the Ames Center (task research).

The formation of RIACS is part of a larger plan within NASA to significantly augment their capabilities in computer science. Having determined that nearly all their major long term goals and future missions depend critically on advances in computer science, NASA decided to support several centers of research in this discipline. These centers will perform computer research pertaining to aerospace problems and will establish and maintain liaisons with industry, academia, and other centers. This approach has been used successfully with three other institutes sponsored by NASA and operated by USRA.

In addition to the core research program, which will center on the vision just outlined, RIACS is chartered to undertake "tasks," which are joint projects with research groups at the Ames Center. Typical tasks include: (1) Graphics Workstation for Computational Fluid Dynamics, (2) Studies of Distributed Operating Systems, (3) Evaluation of Dataflow Architecture, (4) Studies in Computational Chemistry, and (5) Space Station Data Network Concepts.

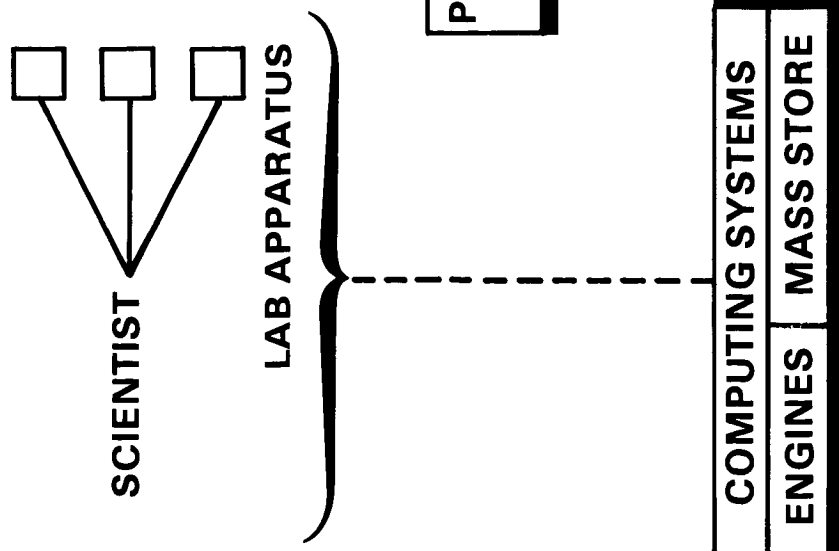
The computing facility consists of a DEC VAX-11/780 used as a mainframe, a VAX-11/730 used as a network gateway, and a Ridge 32 system. Both VAXs are under the control of the Berkeley (BSD) 4.2 version of the Bell Lab's UNIX operating system; the Ridge runs a hybrid system V/BSD UNIX. All machines are connected by a 10Mb Ethernet. The VAX-11/730 is connected to MILNET and the UNIX USENET. General peripherals include a QMS Laser-graphics printer and a Diablo printer. A Silicon Graphics, Inc. IRIS 1500 has been acquired for use in conjunction with a graphics task for the NAS project. RIACS will soon establish direct connection to the NAS networks, giving RIACS easy access to the NAS Cray computer for special projects.

RIACS scientists may also arrange access to the general computing facility of Ames, which includes a two-processor Cray X-MP and a CDC Cyber 205.

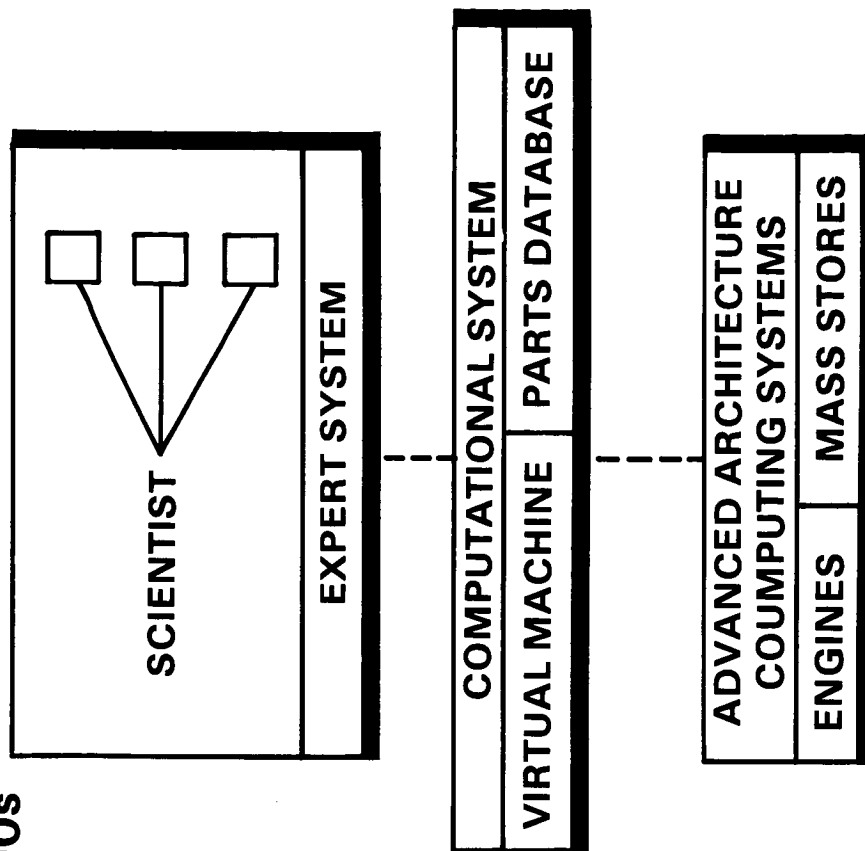
TECHNICAL CONTACT: Peter J. Denning, ARC, (415) 694-6363

RIACS — RESEARCH INSTITUTE FOR ADVANCED COMPUTER SCIENCE

NOW



1990s



COMMUNICATION SYSTEMS

The overall objective of the Communication Systems Technology Program is to provide high-risk components and technology needs to ensure continued U.S. preeminence in satellite communications and permit the distribution of processed data from future high data rate Shuttle payloads, Space Station, planetary spacecraft, and low earth orbit and geostationary orbit platforms.

Major sub-elements include research and technology development in microwave amplifiers (guns, cathodes, collectors, slow wave structures), solid state devices (generic technology at X-, Ku-, Ka-, and V-band, monolithic GaAs Integrated Circuits at Ka-band), antenna technology (monolithic 30/20 GHz array feed, precision reflectors, antenna analysis capability, large aperture antenna feed technology and near-field antenna test capability), microwave intersatellite links, and communications technology for Space Station proximity operations. Potential uses include science and applications missions, space platforms, Space Station, military radar, electronic countermeasures and commercial satellite applications.

PROGRAM MANAGER: Dr. Martin M. Sokoloski
NASA/OAST/RC
Washington, DC 20546
(202) 453-2864

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PROGRAMMABLE MASK TECHNOLOGY

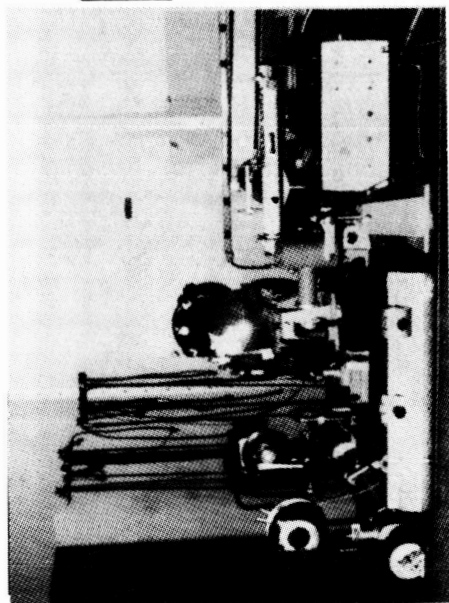
Optical data processing systems are dependent on the accurate and reliable interpretation of data contained in some form of radiant energy. Typical categories that require some type of information processing in the optical wavelengths are pattern recognition, robotic vision, dynamic displays and Fourier transform analysis. Until recently, available information processing techniques were based primarily on the use of computers. The parallel processing characteristics of programmable mask optical processors obviate a considerable portion of the software complexity and, because of the intrinsic traits of optical phenomena, enhance system reliability. A programmable mask is a device that can be used to process or modify an optical signal containing data as a variation of intensity, polarization, frequency or phase to produce a desired information output. Devices available for the implementation of programmable masks are in a state of rudimentary development. More research to provide performance that will more nearly approach theoretical limits and make the techniques useful for space applications is required.

Under this program, various devices employing a diversity of physical phenomena are being examined. Techniques such as liquid crystal light valves (LCLV), deformable mirror devices (DMD), magneto-optic modulators, acoustic-optic processors, microchannel spatial light modulators and optical bi-stable crystal units are all capable of parallel processing of two- and, in some cases, three-dimensional data. Laboratory investigations are being made to uncover performance limitations of available devices. Technology development has been initiated to alleviate these limitations in two device areas, the LCLV and the DMD. The processing system is also being studied to implement holographic memory devices.

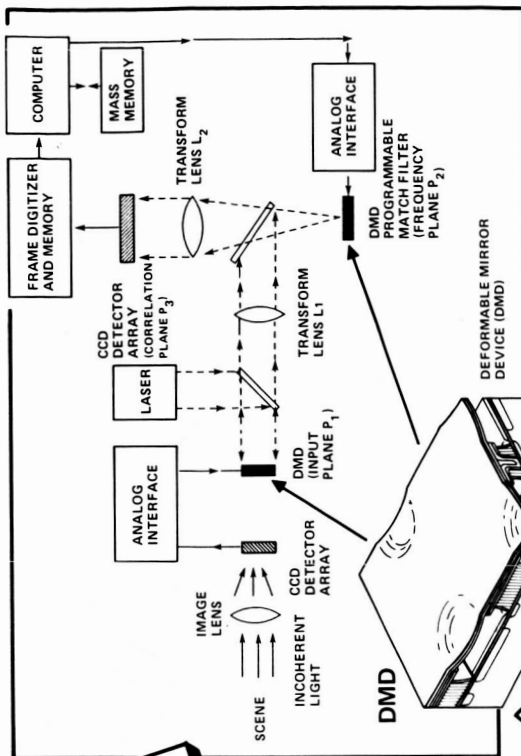
Cadmium sulfide LCLV testing in FY 84 revealed several performance limitations. To improve the performance of these devices, a silicon LCLV was developed. Testing of this device is now in progress. The DMD technology was reviewed and a modified design developed. Fabrication of devices with new designs is now in progress. A joint program involving OAST, NASA/Technology Utilization, and the U.S. Army was developed to accelerate the development of DMD devices and is now being implemented.

TECHNICAL CONTACT: Harry Erwin, JSC, (713) 483-3669
Kumar Krishen, JSC, (713) 483-5518

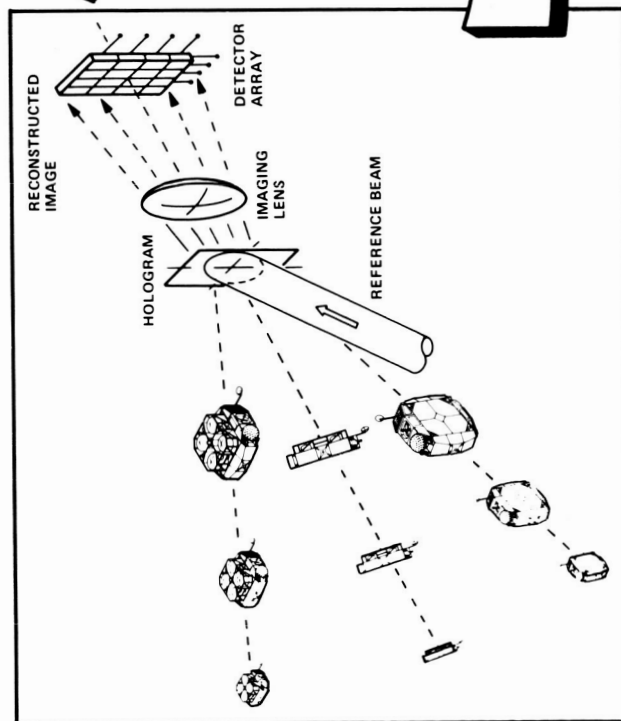
PROGRAMMABLE MASK TECHNOLOGY



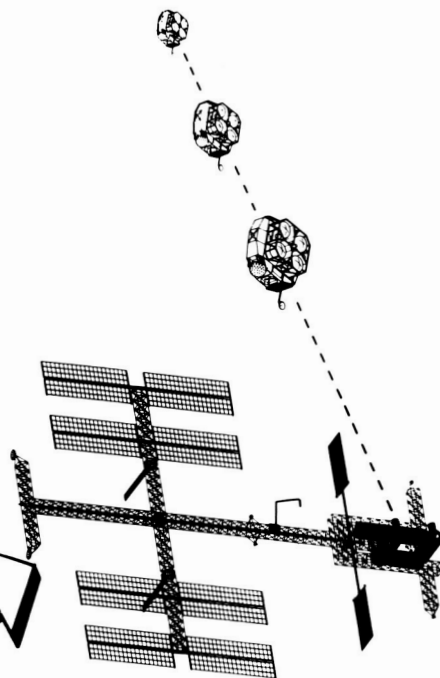
DEVICE TESTING



OPTICAL CORRELATOR



HOLOGRAPHIC VIEW STORAGE



APPLICATION

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ANTENNA SYSTEM TECHNOLOGY: SPACE STATION ANTENNA ANALYSIS

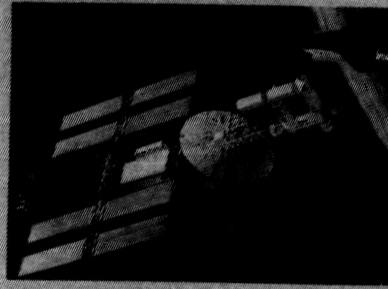
Space Station Analysis methods are being developed at the Langley Research Center that will be used to accurately predict the performance of a multitude of communication and tracking systems. This activity was proposed to OAST through the auspices of the Space Station Communication Technology Working Group, and was funded at a 100 K level of effort beginning in FY 1983. This antenna analysis effort for Space Station is an extension of the Aircraft Antenna Prediction Codes developed by LRC and the Ohio State University.

The basic objective of the Langley Space Station antenna tasks is to provide a verified and documented computer code for use by industry in Phase-B activities. An initial step toward developing this analytical capability has been taken, but the degree of completion and subsequent documentation is dependent upon augmented OAST support. Analysis results and experimental verification tests were accomplished in FY 84 using the scale models of the space station configuration studied by the Concept Development Group (CDG) at NASA Headquarters.

The antenna pattern analysis method includes the effects of complex structures and will be useful in identifying the deficiencies of radiation characteristics exhibited by candidate antenna systems. For example, a photograph of a space station subscale model is shown during antenna pattern tests. Also presented are calculated volumetric patterns for an antenna on a space station and obscuration-blockage predictions for the CDG-Space Station Configuration. This example demonstrates the capability of the analysis method for presenting the pattern coverage on a volumetric basis.

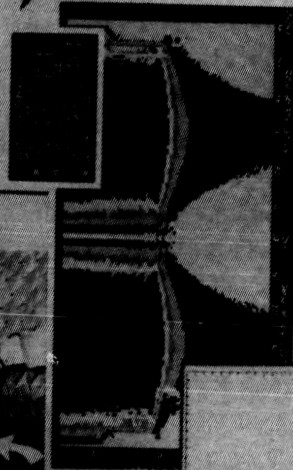
TECHNICAL CONTACT: Thomas G. Campbell, LaRC, (804) 865-3631

ANTENNA SYSTEMS TECHNOLOGY SPACE STATION ANTENNA ANALYSIS



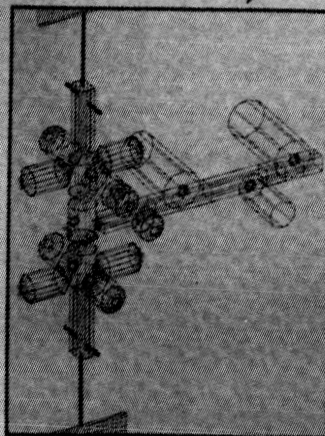
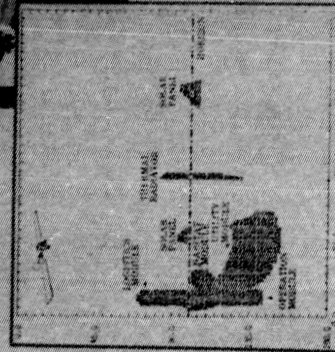
DELIVERABLES

- EFFICIENT ANALYTICAL OBSCURATION METHODS



TESTING/VERIFICATION

- ANTENNA PATTERN MEASUREMENT
- SPACE STATION OBSCURATION ANALYSIS
- VALIDATION PREDICTION METHODS



TECHNOLOGY CHALLENGE

- OBSCURATION EFFECTS ASSESSMENT
- EFFICIENT ANALYTICAL METHODS

ANTENNA SYSTEM TECHNOLOGY: MESH MATERIALS CHARACTERIZATION

A gain degradation problem was observed on several flight deployable antennas for the Tracking and Data Relay Satellite (TDRSS) in 1980. The problem was eventually attributed to the corrosive contacts that increased the ohmic losses of the mesh material, and thereby identified the need to develop a quantitative method for characterizing the electromagnetic properties of mesh materials.

The gain degradation problem is severe for a communication mission, but emissivity values must be extremely low and nearly constant for radiometer missions. A mesh characterization program has been initiated at the Langley Research Center to address these factors. Two experimental test configurations have been developed, (1) an enclosed system using a liquid nitrogen cold load and (2) an open bucket reflector system that reflects the sky brightness temperature into the mesh target and radiometer system. The transmissivity, reflectivity and emissivity values are determined through interactive procedures using mesh, absorber materials and precision calibration splash plates and target conditions. Advanced, proprietary mesh material has been measured and found to be in the range of acceptability for radiometer missions using large space antennas.

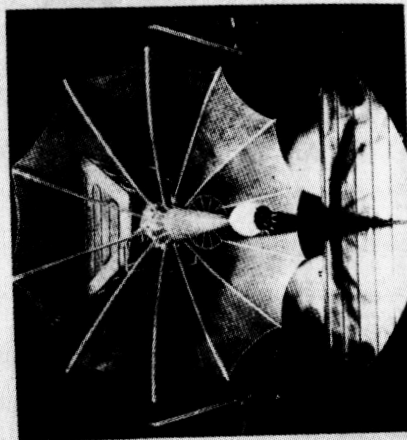
The Naval Research Laboratory has requested that the mesh measurement laboratory be used to evaluate candidate materials for the NROSS satellite. The mesh material for the 15-meter antenna as well as samples from General Dynamics-Convair have been tested. The recent results were reported at the Large Space Antenna Conference held at the Langley Research Center during December 4-6, 1984. Further improvements and characterizations of mesh materials based on an improved experimental set-up are proposed for FY 86.

TECHNICAL CONTACT: Thomas G. Campbell, LaRC, (804) 865-3631

ANTENNA SYSTEMS TECHNOLOGY MESH CHARACTERIZATION

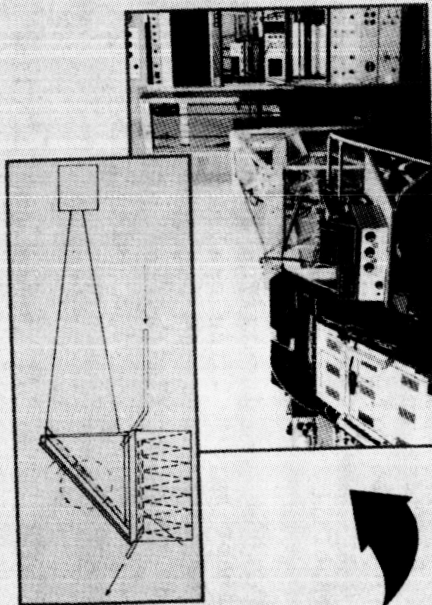
THERMAL STABILITY/REFLECTIVITY

29



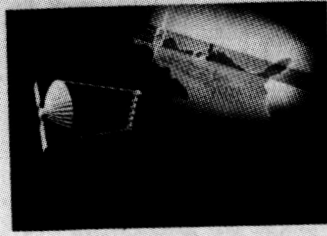
TECHNOLOGY CHALLENGE

- THERMAL STABILITY
- HIGH REFLECTIVITY
- LOW EMISSIVITY



TESTING/VERIFICATION

- COMPLETED EVALUATION
OF TDRSS AND GALILEO
MESH



FUTURE APPLICATIONS

- EARTH OBSERVATION
SYSTEMS
- EARTH SCIENCES
 - SEA SURFACE TEMP
 - SALINITY
 - SOIL MOISTURE

1990'S

1985-6

1984

MANNED SPACE STATION COMMUNICATION AND TRACKING TECHNOLOGY

The design of the communication and tracking (C&T) system for the Initial Space Station is being pursued to satisfy the following goals: (a) significantly reducing Space Station operational constraints and the risk/cost of operations, (b) providing lower cost alternatives to what can be implemented at the present time, and (c) developing technology needed for cost-effective modular growth of the Space Station. The objective of the technology program is to identify and develop needed subsystems/systems to satisfy these goals. For the Initial Operating Capability (IOC), the areas of technology development are the antenna, RF systems, laser ranging and tracking and television.

Technology development in antenna systems is aimed at solving three problem areas: (a) spherical antenna coverage in the near zone, (b) simultaneous links to several near and far satellites/targets, and (c) link requirements which cover several bands (S-, X-, and Ku-bands) and can be satisfied with a single multiple-use antenna. Through this effort, both the size and the number of antennas required for the Space Station (using presently available systems) will be reduced significantly without operational compromises. Two cost-effective designs identified as a result of FY 84 effort are the multi-beam/multi-band antenna for far-zone and the conformal phased array in the near zone. The design of the RF system will need to be optimized in frequency assignments and coding schemes to realize higher performance in power levels, sensitivity, and dynamic range. The RF system is envisioned to have multi-access capability to accommodate links in the S-, X-, and Ku-bands.

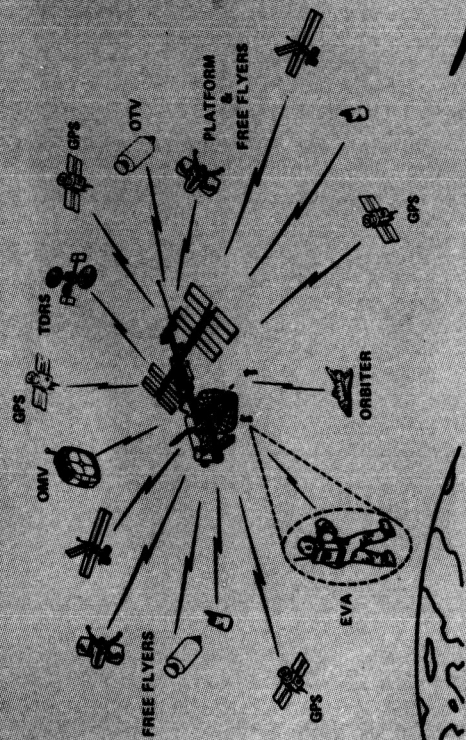
An automatic soft-docking capability has been identified as a requirement for the Space Station. This capability can be provided by a sensor system which can measure relative position, velocity and attitude between many different types of spacecraft and the Space Station. Presently available microwave systems have near-range and very low velocity limitations. Ranging in the optical region using lasers provides the needed accuracy. A feasibility design using heavy, non-flyable components was bread-boarded in FY 84.

Several limitations exist in both the radio frequency and hardline intravehicular communications. Infrared implementation provides the needed enabling technology with potential for high data handling (e.g., closed circuit television). A four channel duplex breadboard was developed in FY 84 to demonstrate this secure and highly RF immune system.

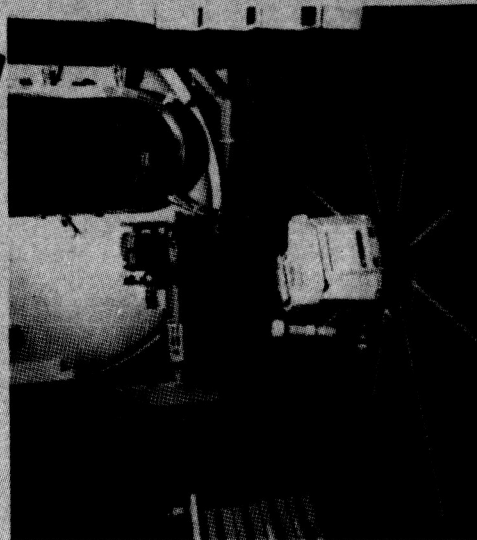
Television systems are envisioned as a priority sensor for many operational aspects of Space Station. The use of television systems in Space Station is anticipated to encompass image processing for automation and proximity operations. Television system implementation can be done in a cost-effective manner by developing hardware resulting in increased reliability, longer lifetimes and reduced size, weight and power. A breadboard of the conceptual design identified in FY 84 will be developed in FY 85/86.

TECHNICAL CONTACT: Kumar Krishen, JSC, (713) 483-5518

SPACE STATION COMMUNICATIONS AND TRACKING TECHNOLOGY



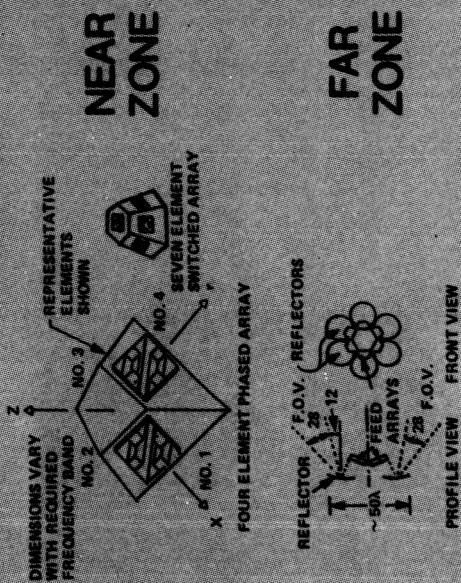
LINKS
(COMPLEXITY)



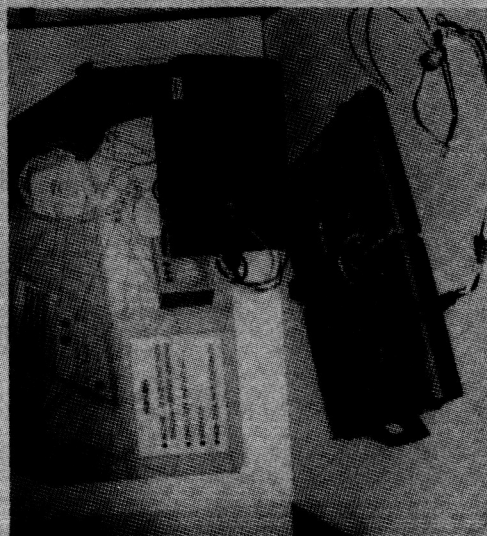
LASER DOCKING SYSTEM
LABORATORY MODEL

GOALS

- COST-EFFECTIVE SYSTEMS
- AMENABLE TO GROWTH
- REDUCED OPERATIONAL CONSTRAINTS



ANTENNA DEVELOPMENT CONCEPTS



INFRARED INTRAVEHICULAR
COMMUNICATIONS BREADBOARD

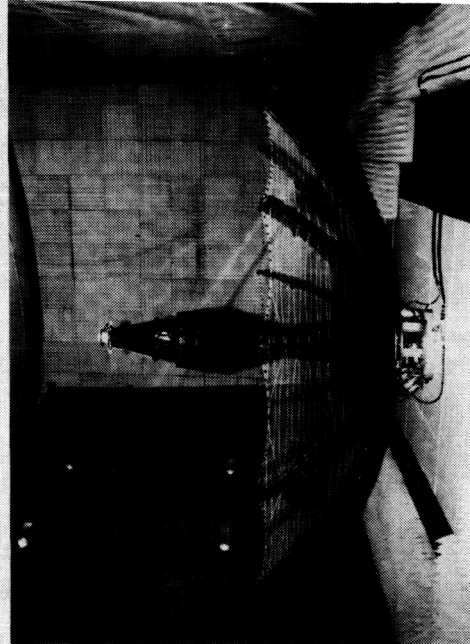
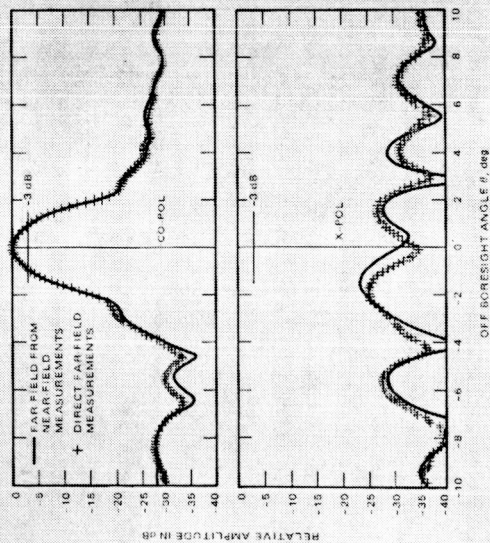
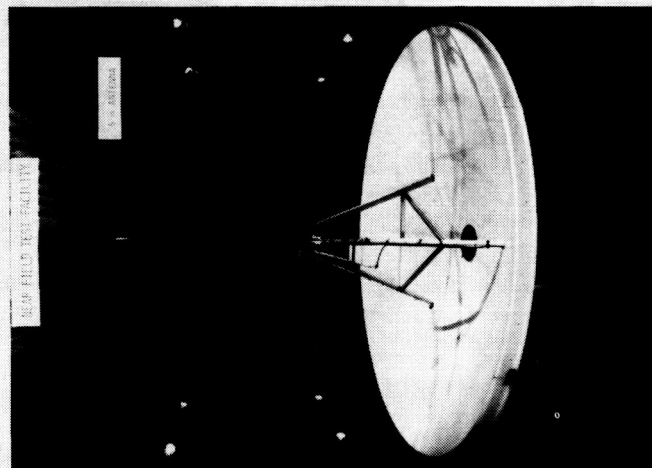
NEAR FIELD MEASUREMENT TECHNIQUES

Near-field measurement techniques enable the determination of far field performance of large and fragile antennas under a controlled indoor environment without using very long outdoor ranges. A new near-field measurement technique, referred to as the plane-polar measurement technique, has been developed and tested. The near field of the antenna is measured by a probe moving in a linear direction while the antenna rotates about its axis. Once the amplitude and phase of the near-field measurements are recorded, they are transformed via Jacobi-Bessel expansion to determine the far-field patterns.

To evaluate the validity of the program, a linearly-polarized 5-m parabolic reflector operating at S-band was tested. The reflector's far-field patterns from both the near-field construction and outdoor far-field measurements were then compared (middle photograph), and close agreement was observed. This technique has been used successfully to determine the far-field performance of the Galileo 5-m flight antenna (right side photograph).

TECHNICAL CONTACT: Richard Dickenson, JPL, (818) 354-2759

FAR FIELD PREDICTION OF ANTENNAS USING PLANE-POLAR NEAR-FIELD MEASUREMENT TECHNIQUE



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MULTIPLE BEAM FEED ARRAY DEVELOPMENT

The photographs show the feed array recently developed for an overlapping cluster feed for the joint JPL/LaRC multiple beam experiment. The feed will be used to illuminate a circular aperture in one of the quadrants of the LaRC 15-m deployable antenna (currently under development) to produce 8 far field S-band beams. The purpose of the JPL experiment is to demonstrate the realizability of generating high performance contiguous beams by using a single antenna aperture instead of using multiple antenna apertures. The primary application is for UHF mobile communication satellite systems.

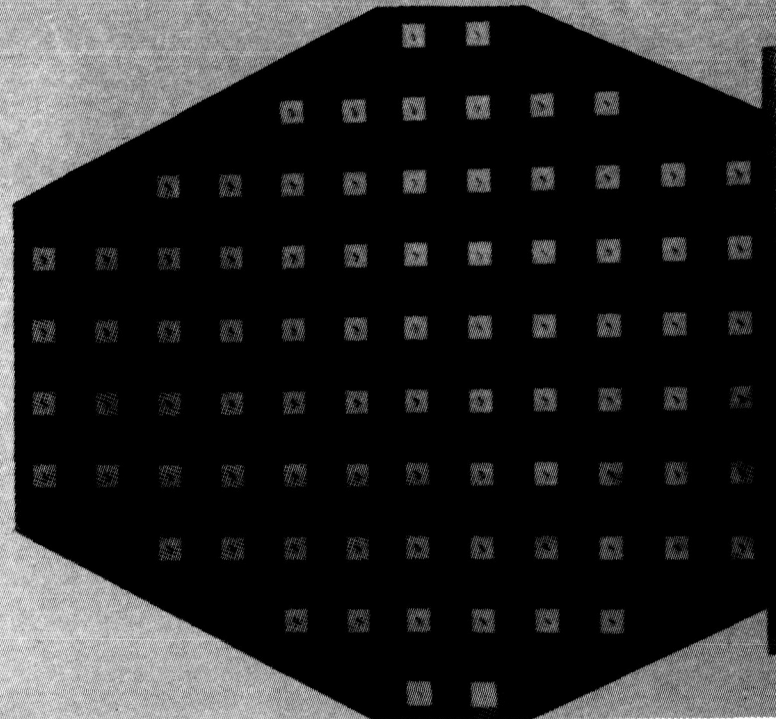
The 8 far field S-band beams are produced by 21 feed elements by using overlapping cluster schemes. Each element is made up of 4 microstrip patches, resulting in a total of 84 patches for the entire feed (left photograph). The microstrip patches are used because they are conformal, relatively thin, and suitable for deployment when a large size feed is required. A microstrip radiator consisting of a square patch with a slanted center slot is employed because it provides circularly polarized radiation by using only one input probe. This feature greatly reduces the complexity of the input power dividing network.

The photograph on the right shows how the input power is fed into a cluster of 7 elements, which generates one beam for the reflector. Input power is then fed into the 4 patches of each element using a 4-way power divider. The arrangement, as shown, is only for the current phase of testing the performance of the 7-element cluster. In the final version, a rather complex beam forming network will be used to feed directly into the input terminals of the 4-way dividers to perform the appropriate power divisions and to achieve the required overlapping clusters of elements. This final beam forming network is currently being fabricated by Ford Aerospace Corporation.

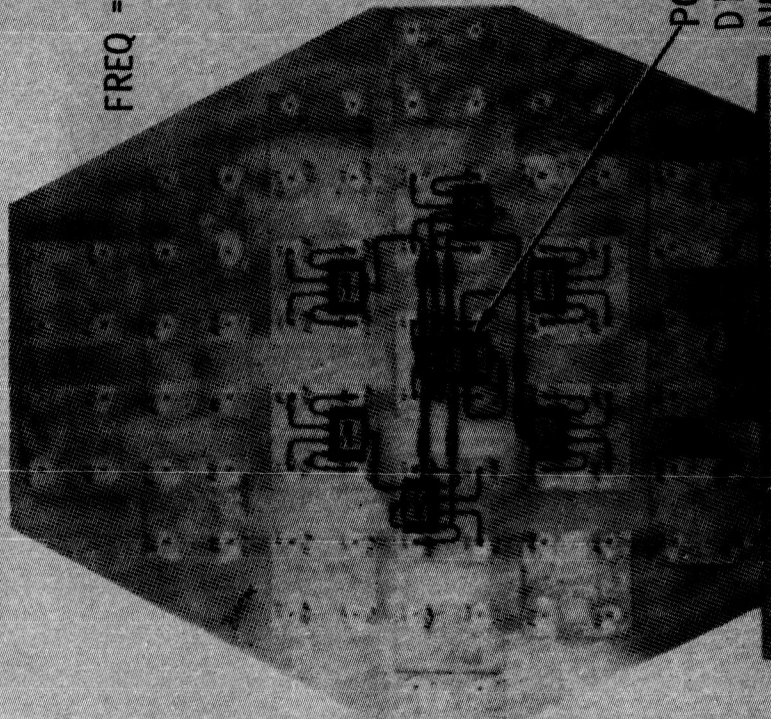
TECHNICAL CONTACT: Richard Dickenson, JPL, (818) 354-2759

8-BEAM FEED ARRAY DESIGN

FREQ = 2.24 GHZ



FRONT VIEW



POWER
DIVIDING
NETWORK
FOR ONE
SEVEN-ELEMENT
CLUSTER

REAR VIEW

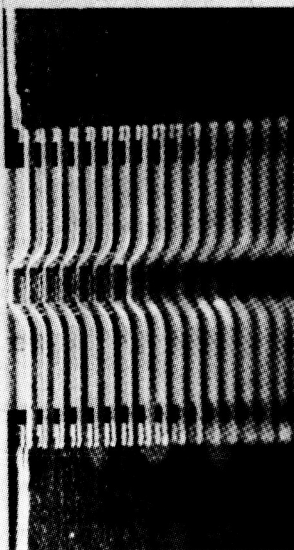
MICROWAVE TWT AMPLIFIER TECHNOLOGY

A traveling wave tube (TWT) amplifies microwave signals by converting the kinetic energy of an electron beam into electromagnetic energy. This is accomplished by propagating the electromagnetic field through the TWT on a slow wave circuit. The electron beam will slow down as it loses energy to the electromagnetic field, eventually losing synchronism and amplification. This effect is overcome by designing the slow wave circuit with a continuously varying dynamic velocity taper resulting in a more efficient TWT.

TWT technology has already been applied to tubes intended for service as amplifiers in Ku-band broadcast satellites, MILSTAR, and ACTS. Development of a super-efficient TWT with a potential application to deep space communication links is planned.

TECHNICAL CONTACT: J. A. Dayton, Jr., LeRC, (216) 433-4000, Ext. 6181

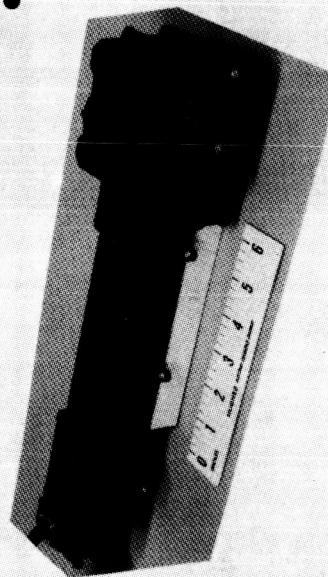
MICROWAVE TWT AMPLIFIER TECHNOLOGY



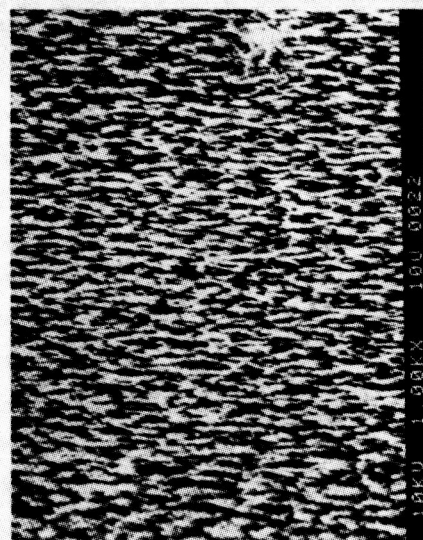
TUNNEL LADDER CIRCUIT

BENEFITS

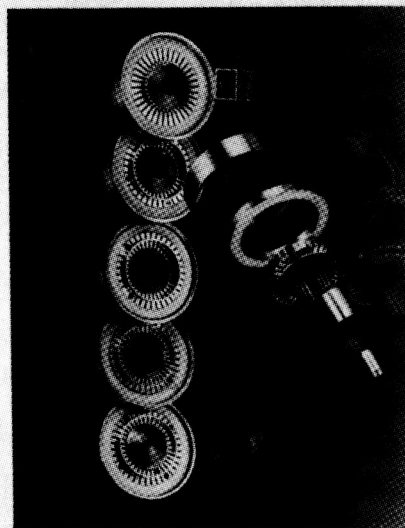
- HIGH EFFICIENCY
- IMPROVED PERFORMANCE
- LONG LIFE
- LOW COST



DYNAMIC VELOCITY
TAPER CIRCUIT



LOW SECONDARY EMISSION
CATHODE MATERIAL



MULTI-STAGE COLLECTOR

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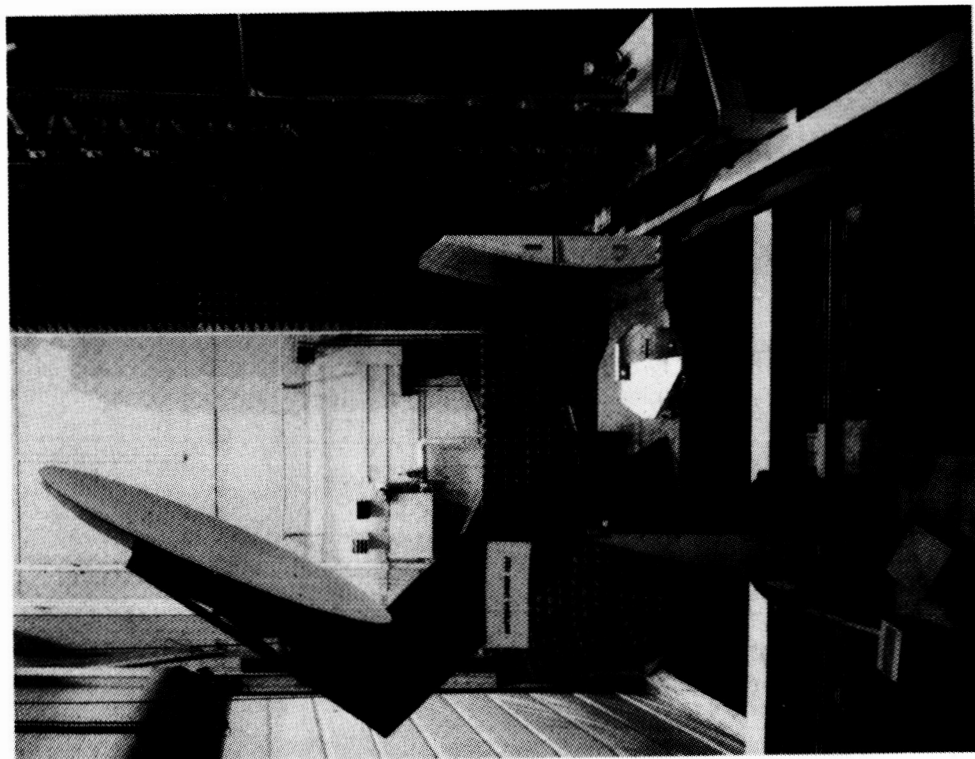
NEAR-FIELD ANTENNA MEASUREMENT CAPABILITY

Near-field testing capability is required for experimental investigation of large, high frequency space communications antennas. The LeRC near-field planar scanner provides a unique combination of large size (22' x 22' scanning plane) and high frequency capability. Due to high precision achieved by combining a rigid, precise mechanical structure and laser alignment and positioning systems, testing to 60 GHz can be accomplished without phase corrections. With corrections, the frequency can be extended to 100 GHz.

Performance has been demonstrated in near-field testing of the ACTS proof-of-concept 30 GHz, 2.8 m multibeam antenna system (as shown). This facility will provide significant support over the next decade to advanced space communications, antenna base R&T and projects such as ACTS.

TECHNICAL CONTACT: C. A. Raquet, LeRC, (216) 433-4000, Ext. 475

NEAR-FIELD ANTENNA MEASUREMENT CAPABILITY



- UNIQUE LARGE NEAR-FIELD PLANAR
SCANNER—22' x 22'
- SUPER PRECISION
 - OPERATION TO 60 GHz
 - EXTENDABLE (WITH PHASE CORRECTION)
TO 100 GHz

APPLICATIONS

- ADVANCED SPACE COMMUNICATIONS
- ANTENNA BASE R&T
- ACTS

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MONOLITHIC GaAs VARIABLE POWER AMPLIFIER

The objective of this program is to develop a 20 GHz monolithic GaAs variable power amplifier (VPA) for advanced communication antenna applications. A major goal for the VPA is the development of a high efficiency module that operates over a wide range of output power levels and can be switched on a TTL compatible digital basis. There are five operating levels of output power/gain/efficiency states varying from 500 MW to 0 MW output power with gains from 20 dB to zero, respectively, and a maximum 15% efficiency. The RF band range is from 17.7 to 20.2 GHz, and the phase shift variation of the VPA is limited to +5 degrees in response to a change in the control state.

Approximately 36 months of the 42 month program have been completed, resulting in the development of a digital amplitude control submodule and a four-stage dual gate FET power amplifier submodule that meets the program goals. The maximum output power/gain/efficiency state for this power amplifier submodule was approximately 450 MW; the gain and efficiency goals were met. The remainder of the program will be used to integrate the control and amplifier submodules into a single monolithic VPA module.

TECHNICAL CONTACT: Thomas J. Kascak, LeRC, (216) 433-4000, Ext. 5560

MONOLITHIC MICROWAVE INTEGRATED CIRCUIT (MMIC) TECHNOLOGY

MONOLITHIC GaAs VARIABLE POWER AMPLIFIER

APPLICATION:

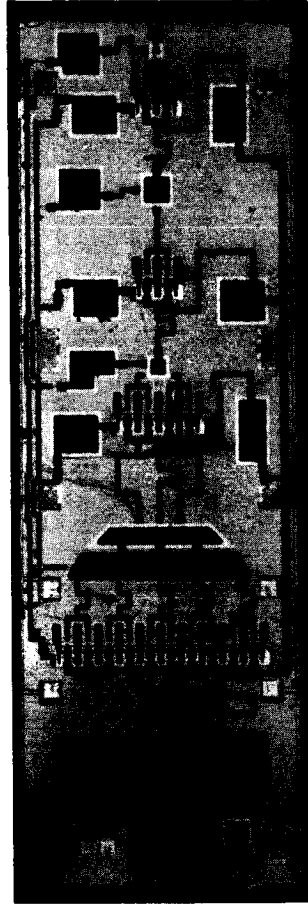
- ADVANCED MILSTAR
- ADVANCED COMMUNICATION APPLICATIONS
- GROWTH SPACE STATION

SIGNIFICANCE OF RESULTS:

- PHASED ARRAY DYNAMIC APERTURE TAPERING:
 - 10-13 db REDUCTION OF ANTENNA SIDELOBES
 - 10 db IMPROVEMENT IN C/I RATIO FOR SPACE COMMUNICATION SATELLITES

RESULTS:

4-STAGE DUAL GATE FET AMPLIFIER
WITH 5 OUTPUT POWER - GAIN - EFF.
STATES ON A 6.45mm × 2.1mm
GaAs CHIP:



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20 GHz MMIC TRANSMIT MODULE

The objective of this program is to develop 20 GHz monolithic transmit module technology for advanced communication antenna applications. Major goals for the transmit module are: a RF band of 17.7 and 20.2 GHz, a RF output power of 200 MW, a gain of 16 dB, an efficiency of 15% and a digitally controlled 5-bit phase shifter.

Approximately 36 months of the 44 month program have been completed; a preliminary version of the monolithic transmit module has been developed that integrates the phase shifter and digital control circuitry, the two-stage buffer amplifier and the three-stage power amplifier on a 4.8 mm x 6.4 mm GaAs chip. Testing yielded an output power of 120 MW and a gain of 15 dB with an operational 5-bit phase shifter. Development is continuing to increase output power and gain, reduce phase shifter insertion losses, increase the GaAs chip processing yields and to fabricate modules.

TECHNICAL CONTACT: Thomas J. Kascak, LeRC, (216) 433-4000, Ext. 5560

MONOLITHIC MICROWAVE INTEGRATED CIRCUIT (MMIC) TECHNOLOGY 20 GHz MMIC TRANSMIT MODULE (VARIABLE PHASE SHIFT)

APPLICATION:

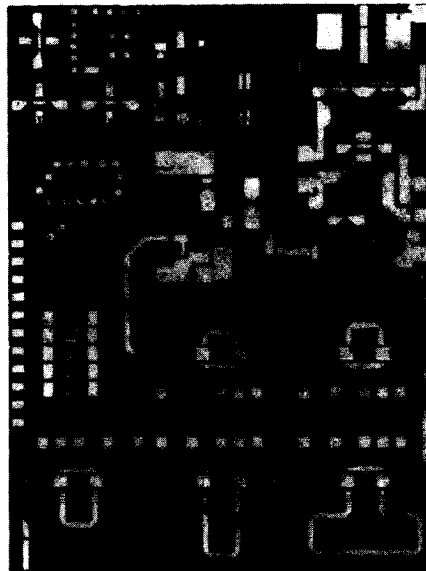
- ADVANCED MILSTAR
- ADVANCED COMMUNICATION APPLICATIONS
- GROWTH SPACE STATION

SIGNIFICANCE OF RESULTS:

- PHASED ARRAY ANTENNA IS FEASIBLE:
 - LOW COST DISTRIBUTED AMPLIFIER APPROACH USING MMIC'S
 - PREDICTED 30% INCREASE IN EFFICIENCY OVER CONVENTIONAL APPROACH
 - HIGH RELIABILITY

RESULTS:

5 SWITCHED LINE PHASE SHIFTER
BITS TOGETHER WITH LOGIC CONTROL
AND AMPLIFICATION ALL ON A
4.8mm x 6.4mm GaAs CHIP:



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AERONAUTICS CONTROLS AND GUIDANCE

The overall objective of the Aeronautics Controls and Guidance Program is to provide the technology for improvement of future civil and military aircraft operations under all-weather conditions and for the exploitation of new concepts and hardware to increase the efficiency, effectiveness and safety of new airplanes and rotorcraft. Major sub-elements include handling qualities and control theory, flight crucial systems, advanced display and guidance concepts, rotorcraft guidance and control, advanced transport operating systems, and multidisciplinary integration.

Support for controls and guidance simulation and system facilities operations is also included. Potential applications for this technology are within the Federal Aviation Administration's air traffic control system operations, the Department of Defense's airplane and rotorcraft operations and commercial airline operations. This technology also has potential applications in new civil and military airplanes and rotorcraft.

PROGRAM MANAGER: Richard J. Wasicko
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NONLINEAR SYSTEM CONTROL DESIGN

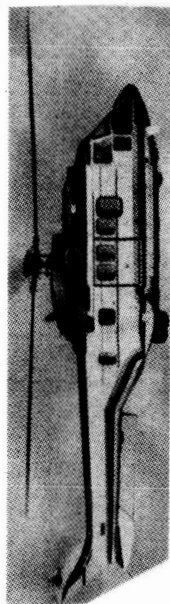
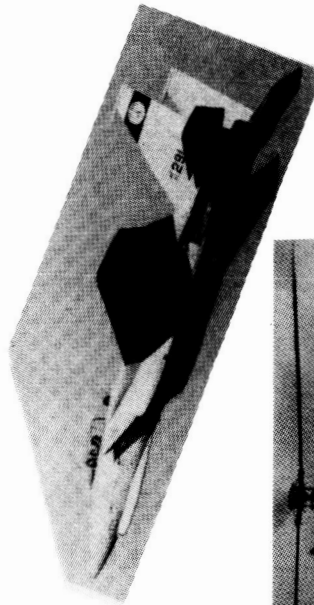
A methodology is being developed for the design of automatic flight control systems for aircraft with strongly coupled, nonlinear dynamics and large operational envelopes. Most existing flight control system design techniques are based on linear models of aircraft dynamics. When nonlinearities which cannot be ignored are present, several linear models defined at different operating points are used, resulting in gain-scheduled linear control laws. This approach becomes very awkward when the size of the operating envelope and the degree of nonlinearity require several scheduling parameters.

A more direct approach has been developed by NASA Ames Research Center. The key step in this new approach is the linearization of system dynamics by transforming the state and control variables. The many effective methods and algorithms of linear control become directly applicable when this step is taken. This systematic design procedure has been applied to the design of a fully automatic flight control system for a UH-1H helicopter and successfully tested in flight.

TECHNICAL CONTACT: G. Meyer, ARC, (415) 694-5444

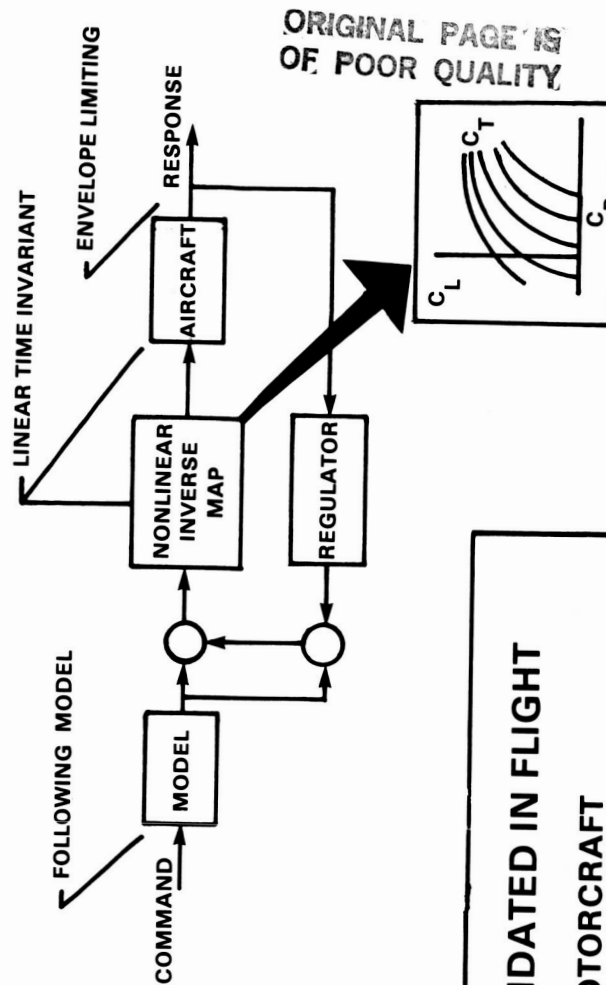
NONLINEAR SYSTEM CONTROL DESIGN

ADVANCED AIRCRAFT



- HIGHLY NON-LINEAR
- HIGHLY COUPLED
- HIGHLY AUGMENTED

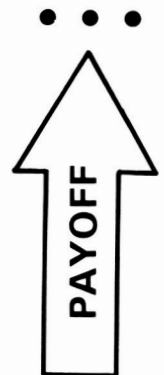
NONLINEAR INVERSE CONTROL CONCEPT



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VALIDATED IN FLIGHT

- ROTORCRAFT
- POWERED-LIFT AIRCRAFT



SIMPLIFIED DESIGN PROCEDURE
PHYSICAL INSIGHT PROVIDED
APPLICABLE TO ENVELOPE LIMITS

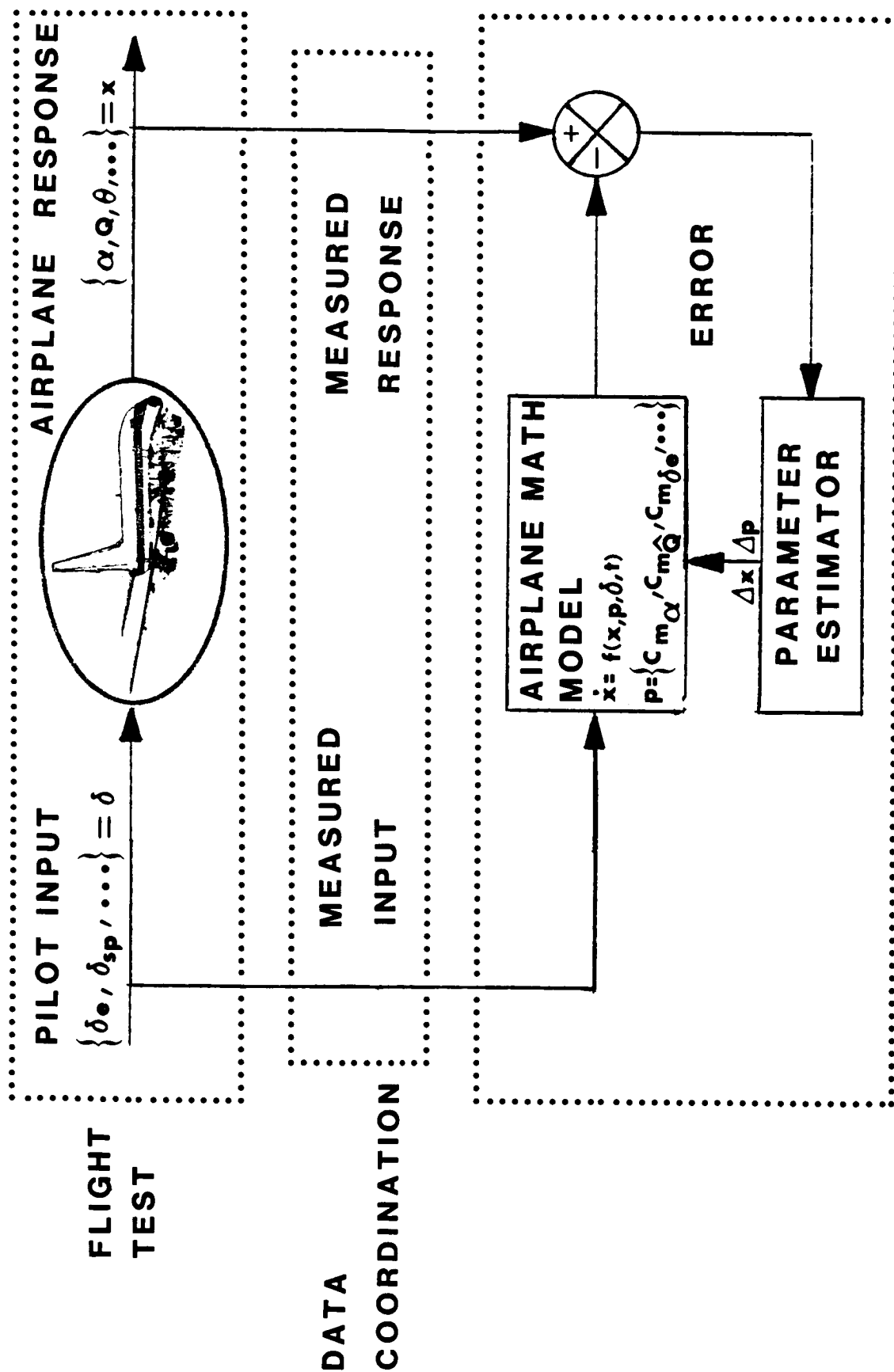
JET TRANSPORT PARAMETER IDENTIFICATION

Recent investigations have revealed the existence of problems in determining an airplane's dynamic model structure and in estimating its aerodynamic parameters at high angles of attack or sideslip from flight test data. The analysis difficulties arise due to the wide speed range, the number of airplane configurations, the complexity of aerodynamic controls and the significant aeroelastic effects which have to be considered.

NASA Langley Research Center and the Boeing Commercial Airplane Company recently undertook a mutually beneficial cooperative activity to promote the application of parameter identification techniques to the analysis of flight test data from a new generation jet transport. The major objective of this effort was to apply NASA parameter identification techniques to the analysis of flight test data obtained by Boeing from a new generation transport. This effort was directed at obtaining a better mathematical model of the jet transport at high angles of attack and/or sideslip using the analysis of data from certain large amplitude maneuvers. NASA provided the computer software and documentation relevant to parameter identification to Boeing, and Boeing provided flight test data and relevant airplane geometric and inertial parameters. A joint final report on this effort will be presented at the American Control Conference in June, 1985.

TECHNICAL CONTACT: J. G. Batterson, LaRC, (804) 865-4591

PARAMETER IDENTIFICATION PROCESS



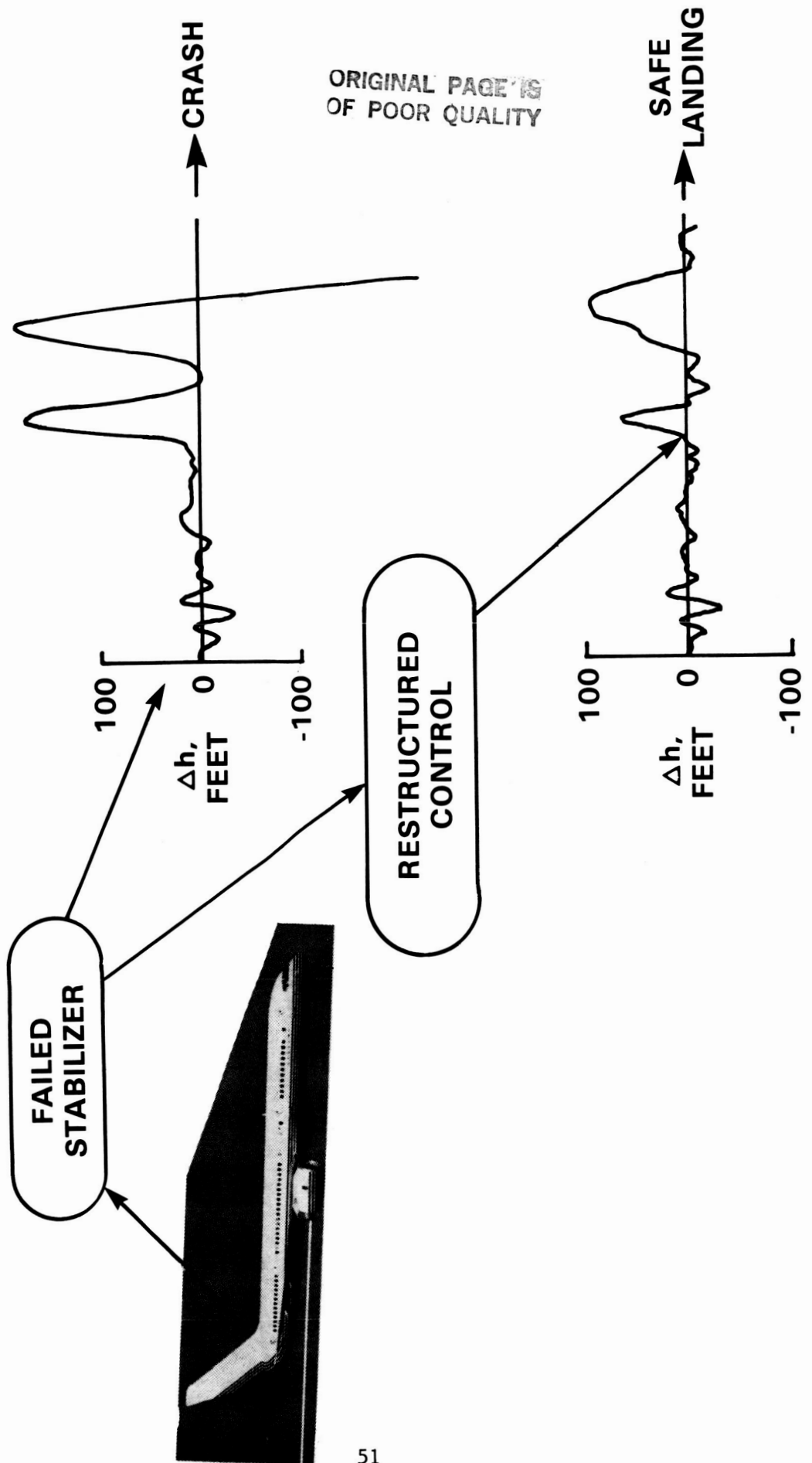
RESTRUCTURABLE CONTROLS

Future aircraft with highly sophisticated controls are likely to have multiple independent failure modes which will be difficult for the pilot to recognize. Such failures may lead to unanticipated sequences of events from which the pilot cannot intuitively recover. Advances in the state-of-the-art in failure detection, failure identification and control system technology suggest that it may be feasible to detect and identify potential catastrophic failures in flight controls and to restructure the controls in real time, allowing continuation of a safe flight and a landing.

The potential benefit of restructurable controls was demonstrated in 1984, using the example of a jet transport on a landing approach in very severe wind shear with turbulence. As illustrated in the accompanying figure, the baseline control system design with four independent longitudinal controls (elevator, horizontal stabilizer, spoilers and engines) regulated altitude error with only moderate excursions in pitch attitude, and successfully tracked the glideslope to a landing. A landing approach in the same wind shear and turbulence environment, but with a stabilizer failure off neutral at 30 seconds, resulted in the aircraft stalling and crashing. Restructuring the control laws to better use the remaining three controls resulted in a successful approach and a safe landing in spite of the severe stabilizer failure.

TECHNICAL CONTACT: A. J. Ostroff, LaRC, (804) 865-3209

RESTRUCTURABLE CONTROLS



RESIDENT BACK-UP SOFTWARE (REBUS)

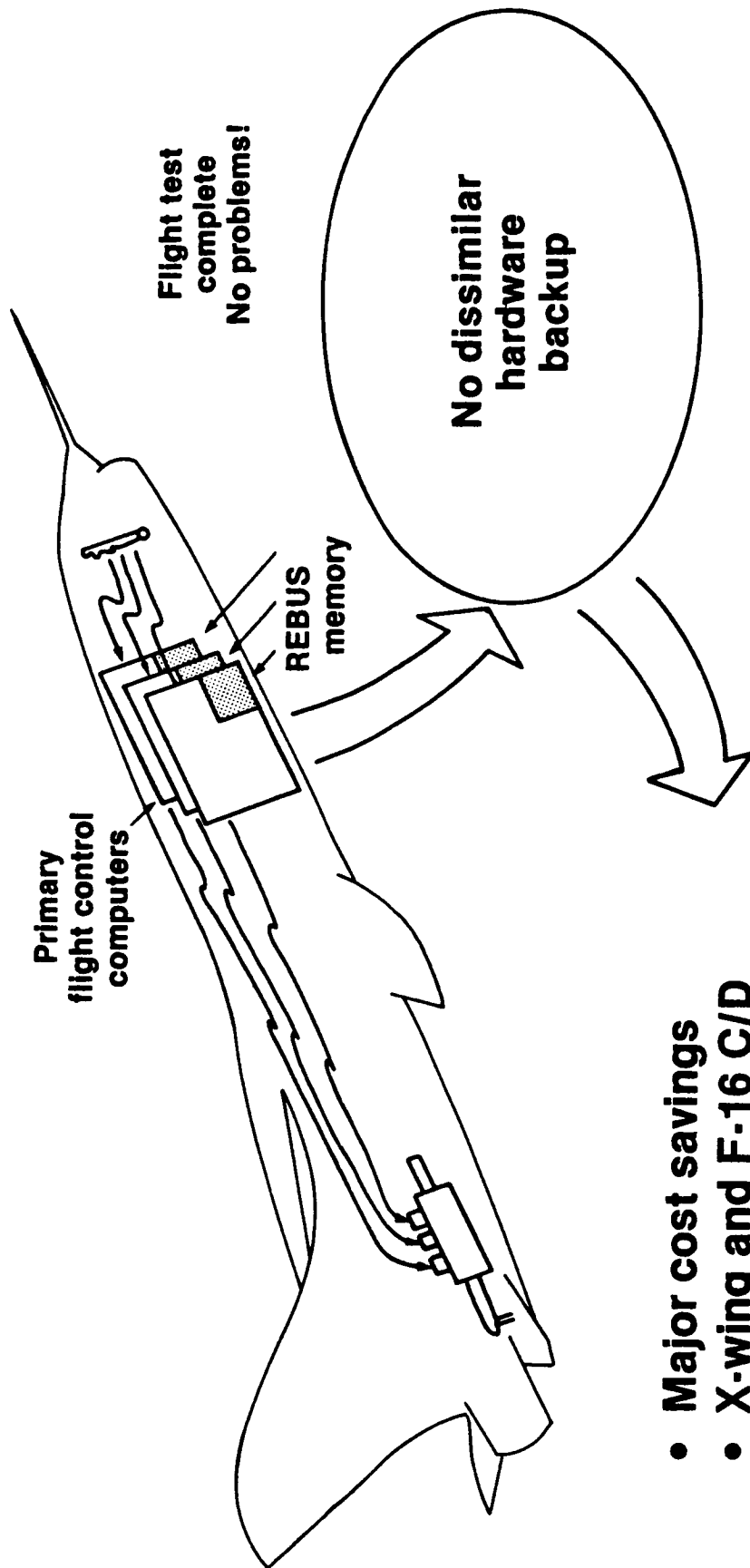
The Resident Back-Up Software (REBUS) concept provides protection for "generic" software errors, which has been a source of worry for digital flight control system designers. It also eliminates the need for dissimilar hardware backup control systems, which was the standard approach to protect against catastrophic results due to generic software errors. A separate memory in the primary digital computers and a small hardware device added to the primary system are used to facilitate switching to the REBUS software. All other processor elements used by the REBUS system are the same as used by the primary system.

Flight tests to demonstrate the REBUS system were conducted in 1984 using the F-8 Digital Fly-by-Wire airplane. Many transitions between the primary and REBUS systems, as well as long duration operation on REBUS to check for interchannel drift, were accomplished. The tests were trouble-free; the system performed in flight in a manner identical to the performance during ground simulation.

The REBUS concept has been adopted by two major programs, the X-Wing and the F-16C/D. Utilizing this system should result in considerable cost savings by eliminating the need for independent backup hardware.

TECHNICAL CONTACT: W. Lock, ARC(DFRF), (805) 258-3432

Resident Backup Software (REBUS)



- Major cost savings
- X-wing and F-16 C/D have committed already

COMPUTER-AIDED RELIABILITY ESTIMATION TECHNIQUE (CARE III)

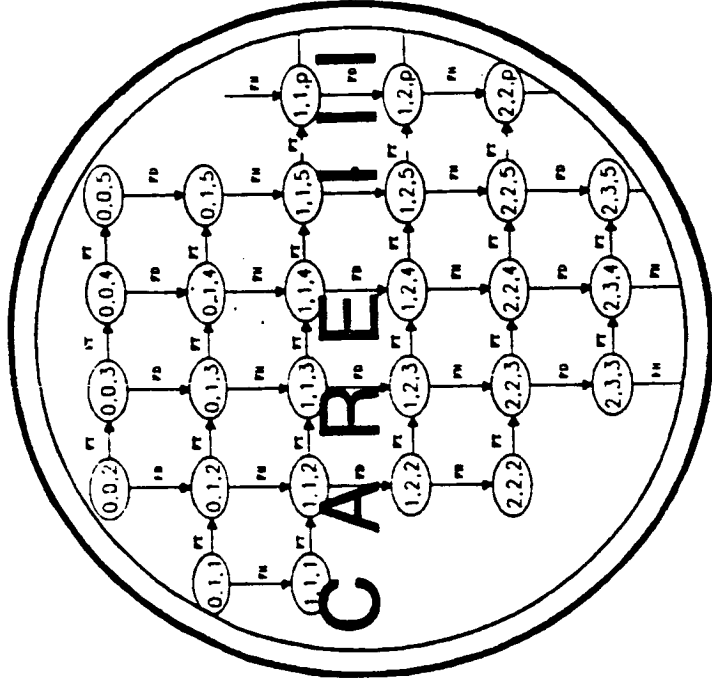
The objective of the Computer-Aided Reliability Estimation work has been the development of a capability that will enable engineers to evaluate flight critical fault-tolerant systems designed for ultra-high reliability. Development of the reliability model and computer program was accomplished over a three year period by the Raytheon Company and NASA Langley Research Center, with inputs from the Boeing Commercial Airplane Company, who contributed the fault tree front-end of the program. The resulting capability is called the Computer-Aided Reliability Estimation, third version (CARE III). Following the development activities, two years were devoted to the validation and enhancement of CARE III by an independent third party, the Boeing Computer Services Company.

A CARE III tutorial and hands-on workshop for aerospace, industry, university and government personnel was held in early 1984; the CARE III trials study to evaluate and validate the program was completed in April, 1984. A CARE III model overview and a user's guide was published in June, 1984, and the CDC CYBER version of CARE III was released to COSMIC for public dissemination in August. A DEC VAX version is expected to be released in 1985.

TECHNICAL CONTACT: S. J. Bavuso, LaRC, (804) 865-3681

COMPUTER-AIDED RELIABILITY ESTIMATION TECHNIQUE CARE III

- RELIABILITY ASSESSMENT TOOL
FOR FAULT TOLERANT SYSTEMS
- TECHNIQUE COMPLETED AND VALIDATED
- PROVIDES INCREASED CONFIDENCE IN
RELIABILITY ESTIMATES
- TRANSFERRED TO INDUSTRY IN 1984



ADVANCED INFORMATION PROCESSING SYSTEM (AIPS)

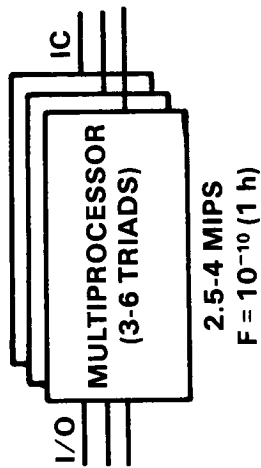
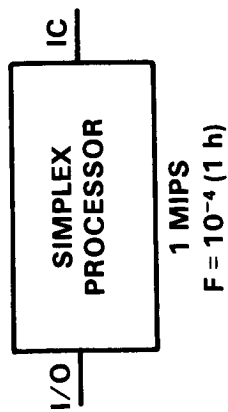
The objective of the AIPS program is to develop and demonstrate a system architecture and the associated design and evaluation methodologies which will effectively serve the need for advanced information processing across a broad spectrum of aerospace missions. Many fault tolerant studies have been conducted in the past, but few have included actual hardware fabrication. Hardware that was built was oriented toward a unique set of specifications and very specific subsystems and applications. In contrast, the AIPS program will emphasize core data processing system requirements and their demonstrated adaptability for many different applications.

A system architecture consisting of fault tolerant computer building blocks, computer interconnection networks, and input/output networks was defined in 1984. The hardware building blocks are augmented by system software which is designed in a service oriented fashion. In addition to providing the standard operating system functions such as scheduling and dispatching of tasks and process synchronization, the system software also provides interfunction communication, input/output device communication, fault handling and resource allocation.

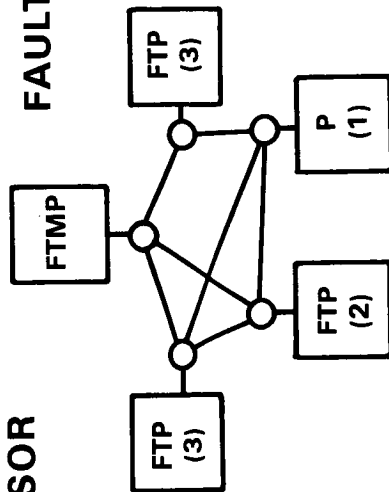
Phase II of the AIPS program began in April, 1984, and is expected to continue for three years. During Phase II, the proof-of-concept system will be implemented in such a way as to emphasize those system attributes which are based on new or immature technology and which promise significant benefits. Examples of these attributes are the application of fault tolerance to distributed systems, and resource management capabilities to enhance reliability and system flexibility.

TECHNICAL CONTACT: E. S. Chevers, JSC, (713) 483-2851

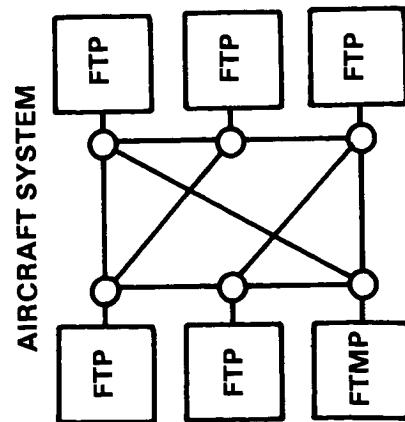
ADVANCED INFORMATION PROCESSING SYSTEM



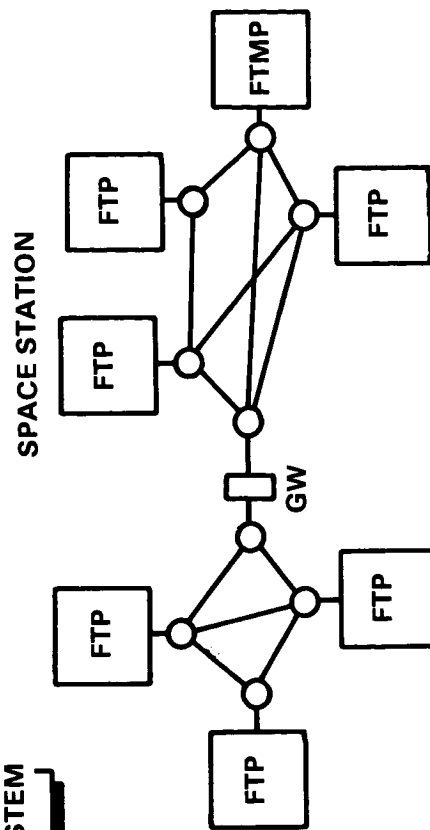
FAULT TOLERANT PROCESSOR



FAULT TOLERANT MULTIPROCESSOR



PROOF-OF-CONCEPT SYSTEM



APPLICATIONS

AVIONICS INTEGRATION RESEARCH LABORATORY (AIRLAB)

The extreme reliability requirements and complexity of system designs for advanced flight critical control systems render current validation processes inadequate. The validation process for such systems requires new analytical techniques, emulation and simulation techniques, mathematical proofs and experimental testing to provide credible assessments and proofs that a system meets its design intent. The Avionics Integration Research Laboratory (AIRLAB) program addresses these issues through the development of new and more powerful modeling capabilities and experimental testing techniques that can be used in confidence to establish the soundness of complex systems.

During 1984, six university teams have been engaged in AIRLAB research on validation techniques. The universities involved and the subjects of their research are as follows:

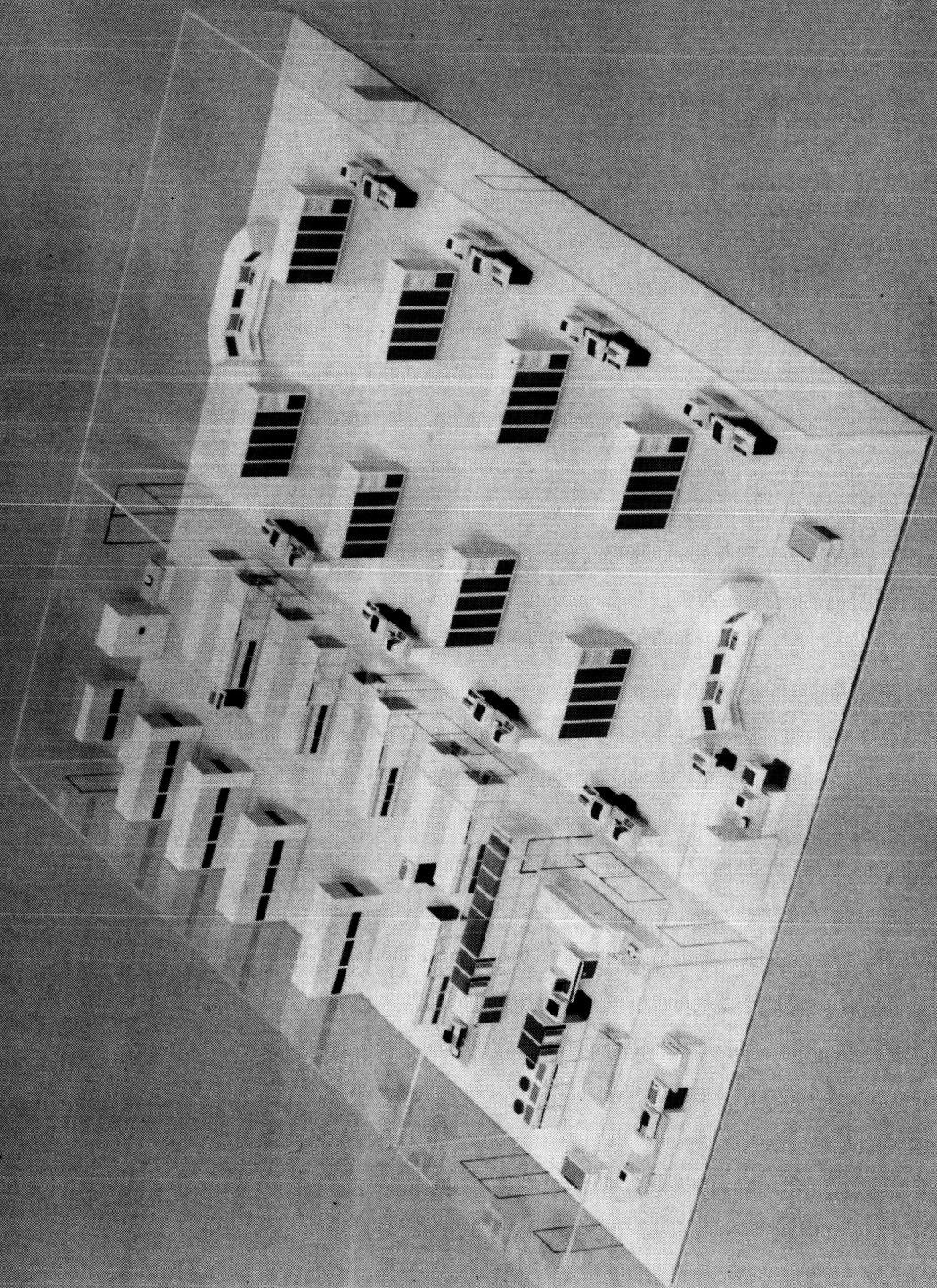
Carnegie-Mellon	Fault-free performance experiments
University of Illinois	Fault-modeling experiments
University of Michigan	Fault-injection experiments, dynamic failure modeling
Old Dominion University	Fault-tolerant software experiment
Howard University	Fault-tolerant software experiment
University of Virginia	Software reliability and fault-tolerant software

The Research Triangle Institutes' work on the development of experiments for collecting software error rate information has presented industrial participation in AIRLAB research. The results are expected to provide confidence in the adequacy of existing software reliability models or lead to the development of a new and better model based on actual software error data.

TECHNICAL CONTACT: A. O. Lupton, LaRC, (804) 865-3681

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AVIONICS INTEGRATION RESEARCH LABORATORY (AIRLAB)



AIR TRAFFIC FLOW MANAGEMENT CONCEPT

Concepts for terminal area traffic management using scheduling and time control (4D) techniques applicable to both 4D-equipped and conventionally equipped aircraft are being studied both analytically and in real time air traffic control simulations at the NASA Ames Research Center. This work is being performed in cooperation with the Federal Aviation Administration.

A recent simulation evaluated the effectiveness of a new algorithm to predict and control large landing time errors of conventionally equipped aircraft. These large errors have been a major obstacle to the automation of terminal area flow management. In the simulation, traffic from two jet routes and a low speed aircraft approach route was merged to land on a single runway. Air traffic controllers from the FAA's Technical Center were provided with indicated airspeed advisories--generated by the new algorithm--to help them control the touchdown time errors of conventionally equipped aircraft.

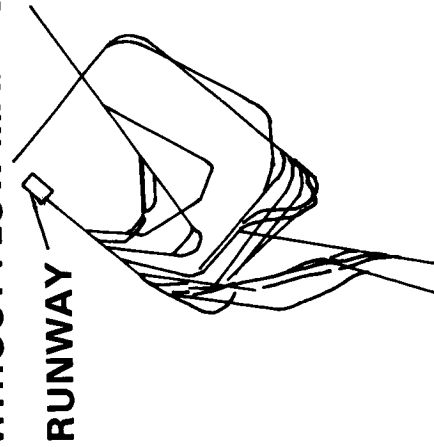
It was found that one or two speed advisories issued by the approach controller reduced initial errors of two miles (at 120 nautical miles from touchdown) to an acceptable twenty seconds at the handoff point for the final controller (25 nautical miles from touchdown). Equipped aircraft, which had negligible time errors, followed their 4D approaches without controller interference. With both 4D equipped and conventionally equipped aircraft able to maintain their scheduled touchdown times accurately, the orderliness of traffic flow in the terminal area was increased and the incidence of conflicts at merge points was minimized. Future studies of this concept will introduce piloted simulations of a helicopter and a jet transport.

TECHNICAL CONTACT: H. Erzberger, ARC, (415) 694-5425
L. Tobias, ARC, (415) 694-5425

AIR TRAFFIC FLOW MANAGEMENT CONCEPT

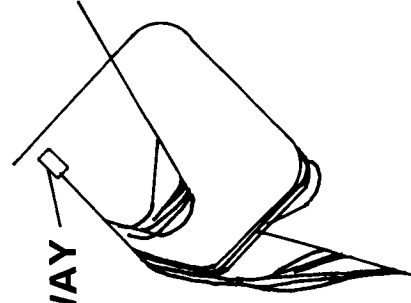
- REAL TIME SIMULATION OF AUTOMATED FLOW MANAGEMENT USING ATC HOST COMPUTER-GENERATED ADVISORIES
- EFFICIENT ATC PROCEDURES DEVELOPED TO HANDLE BOTH 4D FLIGHT MANAGEMENT EQUIPPED AND CONVENTIONALLY EQUIPPED AIRCRAFT
- INCREASED LANDING RATE AND SMOOTHER TRAFFIC FLOW ACHIEVED WITH REDUCED CONTROLLER WORKLOAD

WITHOUT FLOW MANAGEMENT



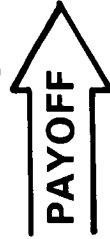
RUNWAY

WITH FLOW MANAGEMENT



RUNWAY

- PLAN TO TEST CONCEPT WITH LIVE TRAFFIC AT DENVER ATC FACILITY



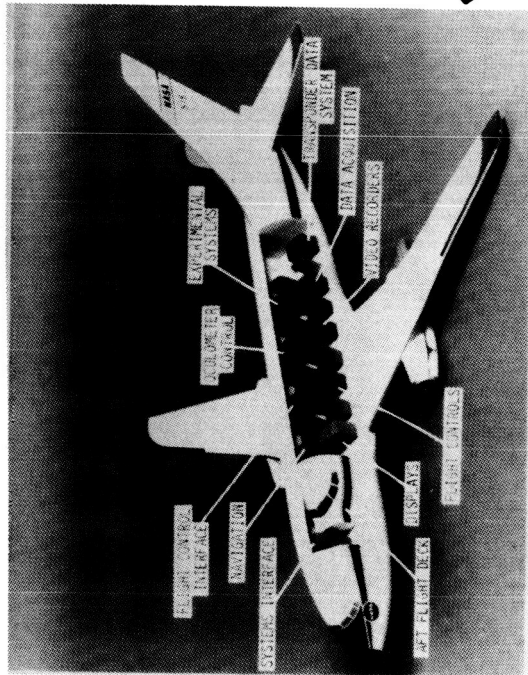
IMPROVED ATC OPERATIONS / SAFETY

ADVANCED TRANSPORT OPERATING SYSTEMS FACILITIES UPGRADE

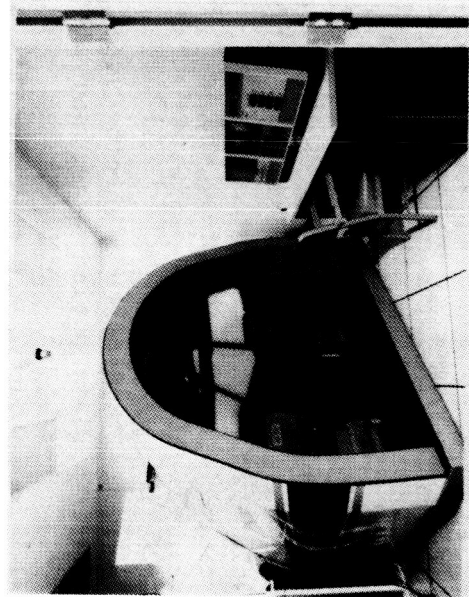
The first phase of the Advanced Transport Operating Systems (ATOPS) facilities upgrade program was completed in 1984 after three years of planning and implementation. This phase encompassed major revisions of the Transport System Research Vehicle (TSRV Boeing B-737 aircraft) experimental system, the Experimental Avionics System Integration Laboratory (EASILY) and the TSRV simulator. The aircraft upgrade program was performed to increase the experimental system's productivity, reliability, flexibility and utility through the use of increased computational power and speed, a higher order programming language, a single global bus, the display of real-time engineering data on strip charts and TV terminals, and improved system status and diagnostic capability. The second and final phase of the ATOPS upgrade program is scheduled to be completed in late 1985. This phase will involve the provision of an "all glass" flight deck in the TSRV aircraft using eight large color hybrid displays, completion of the EASILY as a fully independent facility, and reconfiguration of the TSRV simulator to replicate the upgraded aircraft flight deck.

TECHNICAL CONTACT: W. E. Howell, LaRC, (804) 865-2224

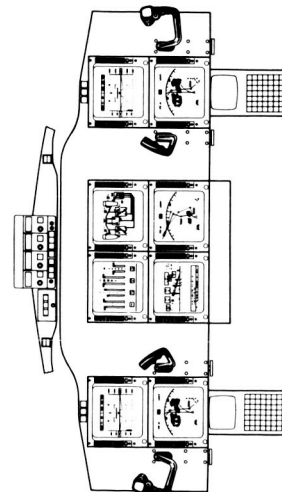
ADVANCED TRANSPORT OPERATING SYSTEMS FACILITIES UPGRADE



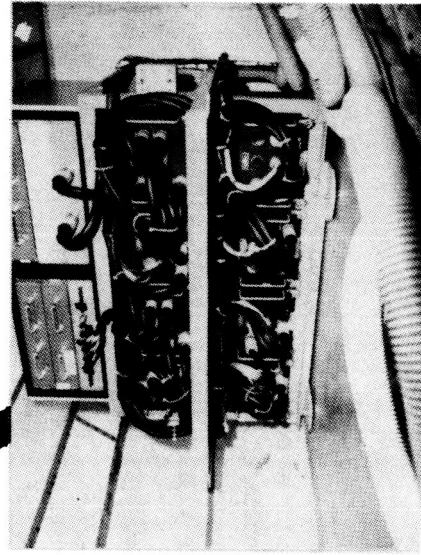
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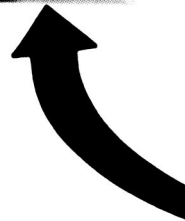
SIMULATOR



DISPLAYS



COMPUTERS



STATISTICAL CHARACTERIZATION OF LIGHTNING DATA

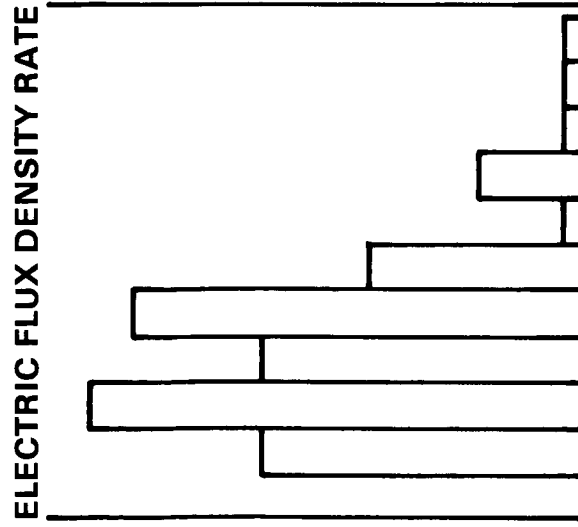
Electromagnetic transients recorded during 176 high altitude lightning strikes to a NASA-operated F-106 airplane were analyzed using a probability plotting method along with a formal statistical test to check the flight data against several statistical models. An estimation method was used to compute quantile estimates for the data which were valid without assumption of parametric models. Approximate confidence limits were then determined for the quantities, and tables were constructed showing how the sample size depended on the precision required of the estimates.

The statistical method developed and applied to the lightning data provides a means to statistically examine the experimental results as to distribution type, and also to examine the worst cases or "tails" of the distributions. The analysis has indicated that the rates of change of electric flux density and current were lognormally distributed, and that the rate of change of magnetic flux density was uniformly distributed. The results of this effort have been published in NASA TP-2252 and provide specific statistical numerical quantification of lightning interaction with fighter-sized aircraft. Previously, such information was known only qualitatively, with essentially no statistical basis.

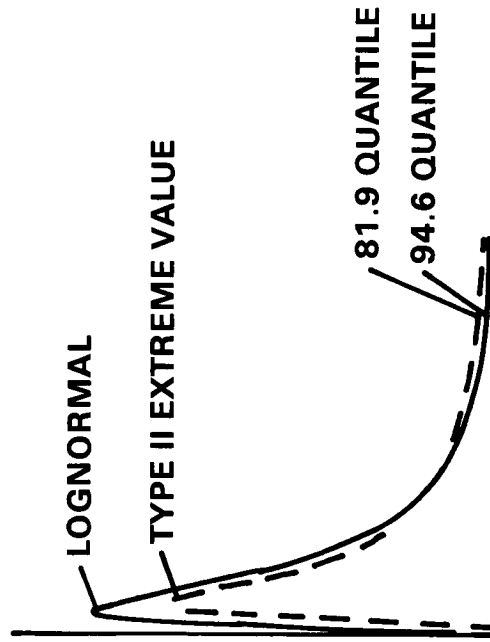
TECHNICAL CONTACT: F. L. Pitts, LaRC, (804) 865-3681

STATISTICAL CHARACTERIZATION OF LIGHTNING DATA

FREQUENCY OF OCCURRENCE
OF PEAK VALUES



SKewed DISTRIBUTIONS



- STATISTICAL DISTRIBUTIONS ESTABLISHED

- EXTREME QUANTILES ESTIMATED

HELICOPTER SATELLITE BASED GUIDANCE--DIFFERENTIAL GPS

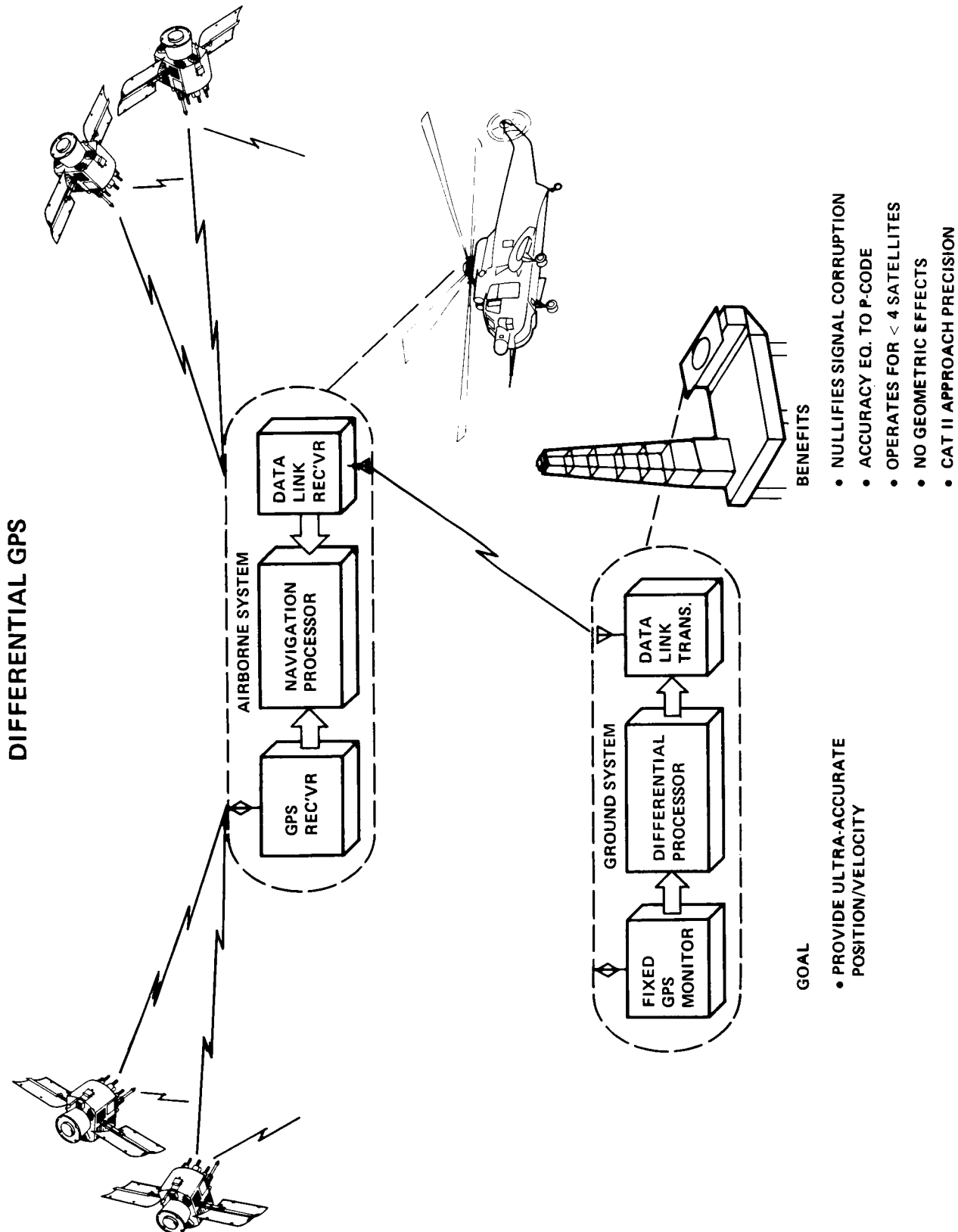
NASA Ames Research Center has a continuing research program to evaluate the use of the NAVSTAR Global Positioning System (GPS) to provide guidance information that can be used to achieve civil helicopter precision approach and landing capability, particularly at remote sites. Differential GPS is an attractive alternative mechanization of GPS in which the airborne system position computation, based on GPS signals, is improved in accuracy by a ground system signal. This procedure is expected to provide significant improvements in performance when compared to conventional GPS system operations.

The additional performance may prove adequate to achieve helicopter precision approach and landing operations in areas not currently served by ground-based guidance systems. Offshore explorations, operations into remote and mountainous terrain and inter/intra city emergency medical rescue are examples of helicopter missions that might be supported by differential GPS guidance.

The airborne part of a differential GPS research system has been under development at Ames Research Center and is being installed in a NASA helicopter. Non real-time differential flight tests were conducted during 1984 using the partially completed airborne system and an off-the-shelf ground reference receiver. The data obtained from these tests should provide an understanding of the characteristics of the error components of the differential uplink correction information and will help establish the ground station's uplink message frequency and data content requirements. The ground based component of the differential GPS research system, installed in a mobile van, is being developed by Ohio University under contract to NASA. It is scheduled to be delivered to Ames Research Center in the fall of 1985, and flight evaluations will follow.

TECHNICAL CONTACT: F. Edwards, ARC, (415) 694-5437

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SPACE CONTROLS AND GUIDANCE

The Space Controls and Guidance Research and Technology Program is directed toward enabling large future spacecraft and space systems such as space station, large mobile communication antennas and high precision segmented reflector astrophysical telescopes. These spacecraft have demanding control requirements for pointing and stabilization, momentum management, build-up and growth accommodation, disturbance management and rendezvous and docking coordination.

To address these requirements, an advanced technology program is underway in system identification, adaptive control, integrated structures/controls design methods, distributed control and advanced sensors. Because the dynamics behavior of large, lightweight deployable/assembled spacecraft is greatly influenced by the ground environment, the testing and verification activity is both ground and space based.

Promising controls approaches and algorithms will be tested in space under NASA's Controls of Flexible Structures Program on a shuttle-attached long flexible beam facility especially designed as a controls research test article. This facility is intended as a national facility; therefore, it is being made available to those industrial IR&D programs designed to develop and test control algorithms.

PROGRAM MANAGER: John D. DiBattista
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CONTROL OF FLEXIBLE STRUCTURES (COFS) FLIGHT EXPERIMENT PROGRAM

The Control of Flexible Structures (COFS) Flight Experiment Program consists of a series of three shuttle-attached experiments specifically designed to systematically evaluate NASA, industry IR&D, university and other government agencies algorithms and techniques for on-orbit systems identification and flexible body control of large flexible structures. This program will serve to validate the enabling technologies for future NASA missions such as the evolutionary space station and large orbital antennas.

The basic test article is a joint-dominated, deployable truss beam 60 meters in length with a 1.2 meter triangular cross section. The beam is sufficiently large and flexible to make the validity of full-scale ground testing questionable. The frequency of the first bending mode is approximately 0.2 Hz, and mechanisms are provided to vary the frequency spacing and cross axis coupling to provide closely-spaced and geometrically-coupled modal pairs. System identification sensors are distributed along the beam, and multi-axis control actuators are provided at two or more locations.

The first flight (COFS-1) will deploy a structural dynamics and active modal damping experiment. The COFS structure is excited by beam-mounted actuators; dynamic characterization data are accumulated and down linked, and ground-based processing identifies the mode shapes, frequency, and natural structural damping. In addition, active damping of the excited beam is evaluated using co-located sensors and actuators.

Distributed control algorithms are incorporated in the flight computer to support the COFS-2 experiment. This experiment validates beam shape and tip position control using flexible body control laws employing several sensor sets and at least two separate actuator sets. As in COFS-1, beam-mounted actuators provide excitation for system identification with the modal characterization data being transmitted to the ground for reduction. Control system parameters are updated in the flight computer via uplink, and distributed control experiments are conducted.

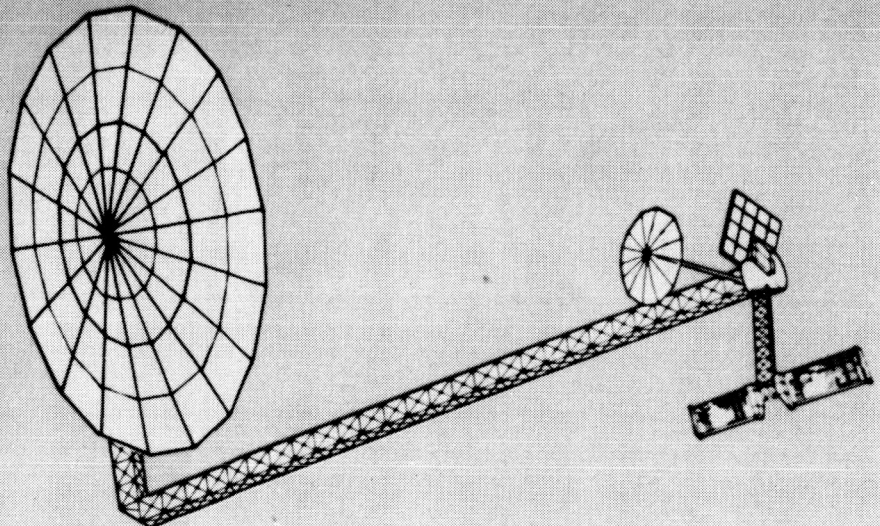
System identification algorithms are incorporated in the flight computer to support the adaptive control experiment of COFS-3. This experiment will validate control of the beam under conditions of time-varying model characteristics or erroneous initial predictions of a modal characteristics. The sensed dynamic characterization data are processed by a systems identification algorithm resident in the flight computer to provide on-orbit, closed-loop control system updates.

Individuals and organizations desiring to use COFS in their research are encouraged to call or write the technical contact.

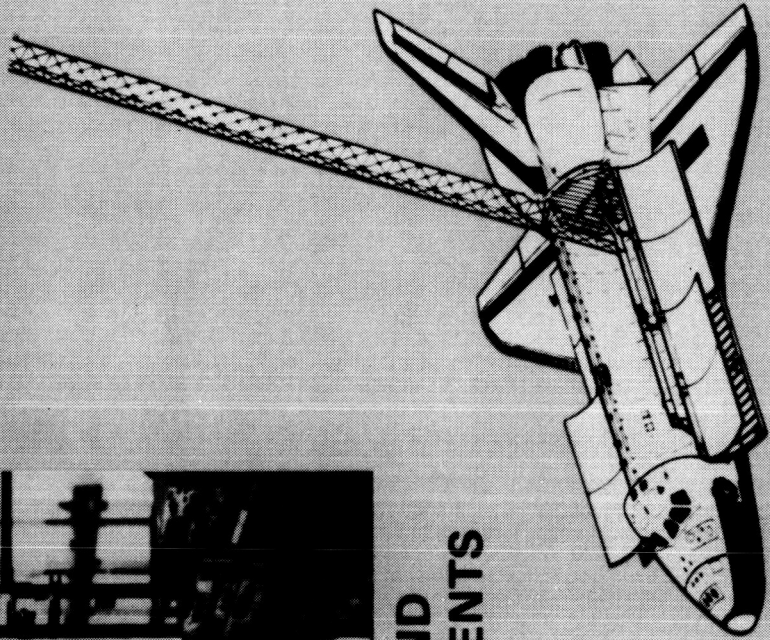
TECHNICAL CONTACT: Anthony Fontana, LaRC, (804) 865-4591

CONTROL OF FLEXIBLE STRUCTURES

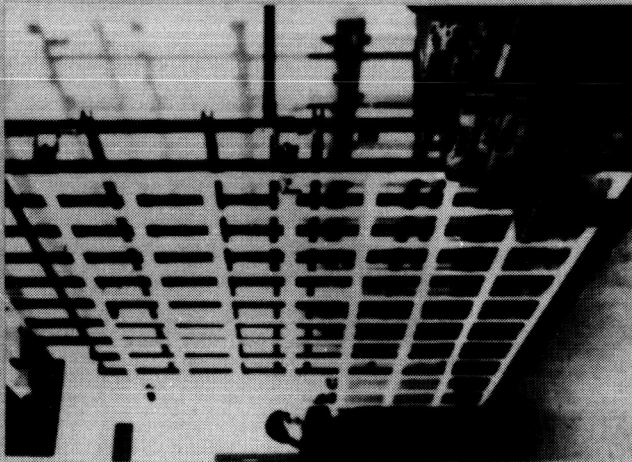
ANALYSIS AND
MODELING



FLIGHT
EXPERIMENTS



GROUND
EXPERIMENTS



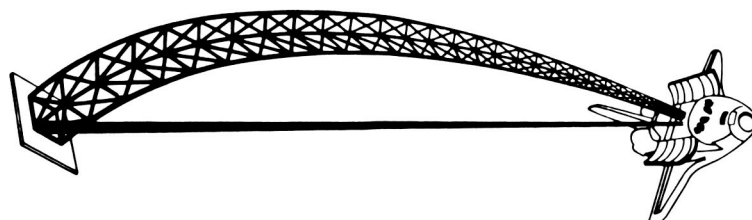
GROUND FACILITY FOR LARGE SPACE STRUCTURE CONTROL VERIFICATION

The Marshall Space Flight Center has developed a facility in which closed loop control of Large Space Structures (LSS) can be demonstrated and verified. The main objective of the facility is to verify LSS control system techniques so that on-orbit performance can be ensured. The facility consists of an LSS test article which is connected to a payload mounting system that provides control torque commands. It is attached to a base excitation system which will simulate disturbances most likely to occur for Orbiter and DOD payloads. A control computer will contain the calibration software, the reference system, the alignment procedures, the telemetry software and the control algorithms. The total system will be suspended in such a fashion that the LSS test article has the characteristics common to all LSS such structures.

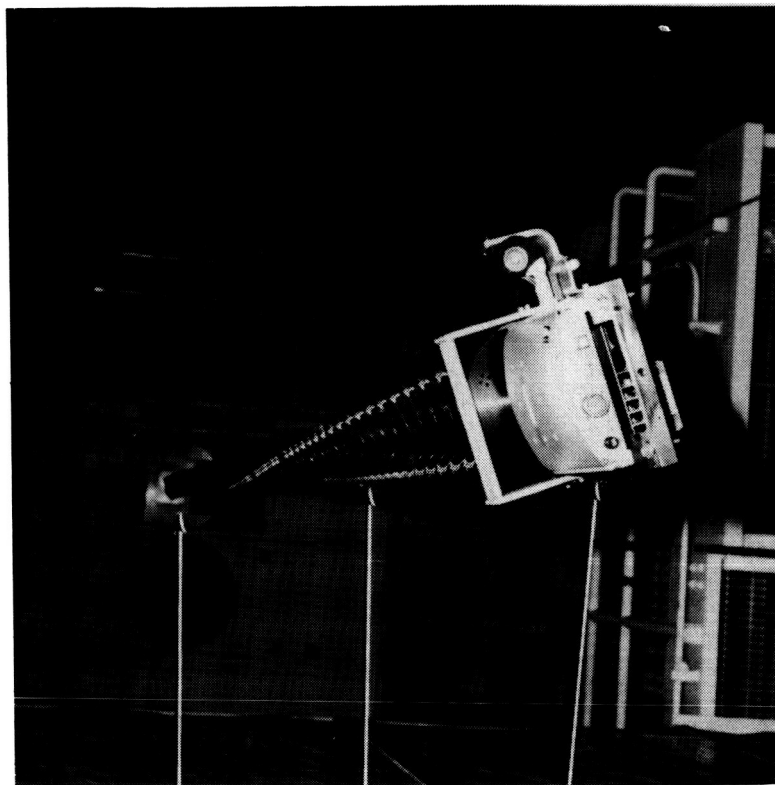
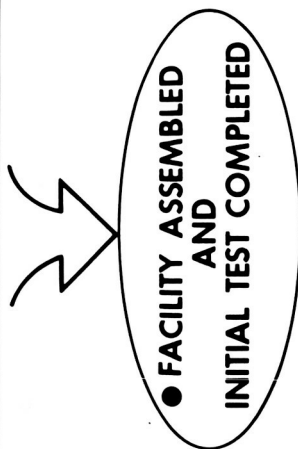
The high bay area in which the ground facility is located has a vertical dimension of 120 feet. With this vertical dimension, the Pinhole Occulter Facility (POF) could be housed in the ground facility so that control verification could be established for the POF. If the POF's 32 meter mast were not available, then the present mast could be "tuned" so that its structural frequencies match the POFs. Once the match is completed, then the POF's control algorithms can be verified. Although the control verification is done in a 1-g environment, the testing should be sufficient to ensure on-orbit success.

TECHNICAL CONTACT: Harry Buchanan, MSFC, (205) 453-4582

STRUCTURES/CONTROLS TEST FACILITY WITH 60' BEAM IN PLACE



PINHOLE
OCCULTER
FACILITY



3 AXIS
CONTROL
GIMBAL

60'
DEPLOYABLE
BEAM

CONTROL
SENSOR
PACKAGE

- VERIFY AND DEMONSTRATE
FLEXIBLE STRUCTURES
CONTROL ALGORITHMS

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ADAPTIVE/DISTRIBUTED CONTROL (GRID APPARATUS)

The NASA Langley Research Center grid apparatus is a 7 ft by 10 ft planar structure made of overlapping aluminum bars and supported by two cables attached to the top bar. It provides researchers a real time control law processing capability having realistic structure, sensors and actuators. The processing architecture is an advanced distributed processing system that employs a central processor and "smart" components (i.e., actuators and sensors with digital processing capability). The structure has a high modal density, expected to be characteristic of many future spacecraft, with 20 vibration modes having frequencies less than 10 Hz. Sensors used to control the grid are rate gyros and accelerometers characteristic of spaceborne units. Similarly, the actuators (torque wheels) are characteristic of spaceborne actuators. Additional noncontacting position sensors that measure the position of the grid at nine locations relative to a fixed backstop provide for evaluation of experiments. These sensors are not characteristic of spaceborne sensors, and are for evaluation only.

Researchers using the grid apparatus can conduct an experiment from a remote terminal in much the same way that a digital computer batch simulation can be conducted. The researcher's operating system is UNOS, which is a UNIX look-alike. Both C and Fortran compilers are provided. Currently, research applicable to the needs of contemporary and future spacecraft is in progress. Areas of immediate focus are system identification, the use of noncollocated sensors and actuators, hierarchical control utilization of "smart" components, adaptive control of flexible (distributed) systems, and automatic failure detection and control system recovery.

TECHNICAL CONTACT: Raymond C. Montgomery, LaRC, (804) 865-4591

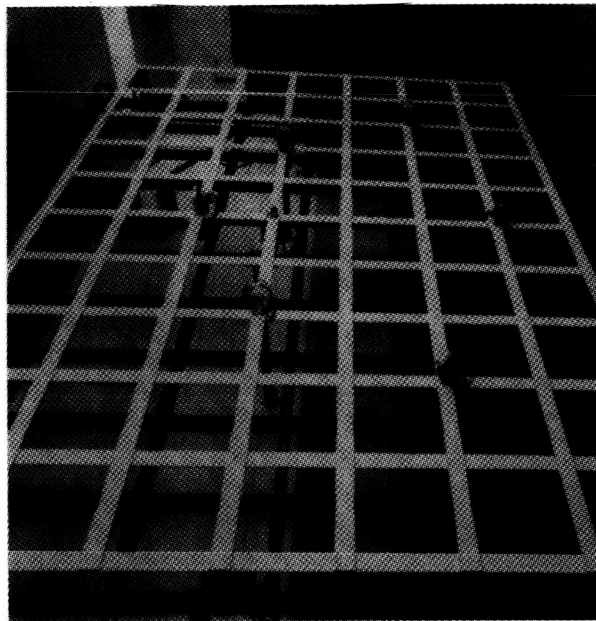
ADAPTIVE/DISTRIBUTED CONTROL GRID APPARATUS

CHARACTERISTICS

- 7' x 10' PLANAR
- 20 MODES LESS THAN 10 Hz
- REAL TIME/DISTRIBUTED
COMPUTER ARCHITECTURE

SENSOR/ACTUATOR COMPLEMENT

- 6 "SMART" TORQUE WHEELS
- 2 SINGLE AXIS RATE GYROS
- 2 THREE AXIS RATE GYROS
- 6 LINEAR ACCELEROMETERS
- 9 NONCONTACTING POSITION
SENSORS FOR EVALUATION ONLY



RESEARCH TOPICS

- SYSTEM IDENTIFICATION
- NONCOLLOCATED SENSORS/ACTUATORS
- CONTROL WITH DISTRIBUTED
COMPUTERS
- DISTRIBUTIVE ADAPTIVE CONTROL
- AUTOMATIC FAILURE DETECTION
AND SYSTEM RECOVERY

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SPACECRAFT CONTROL LABORATORY EXPERIMENT

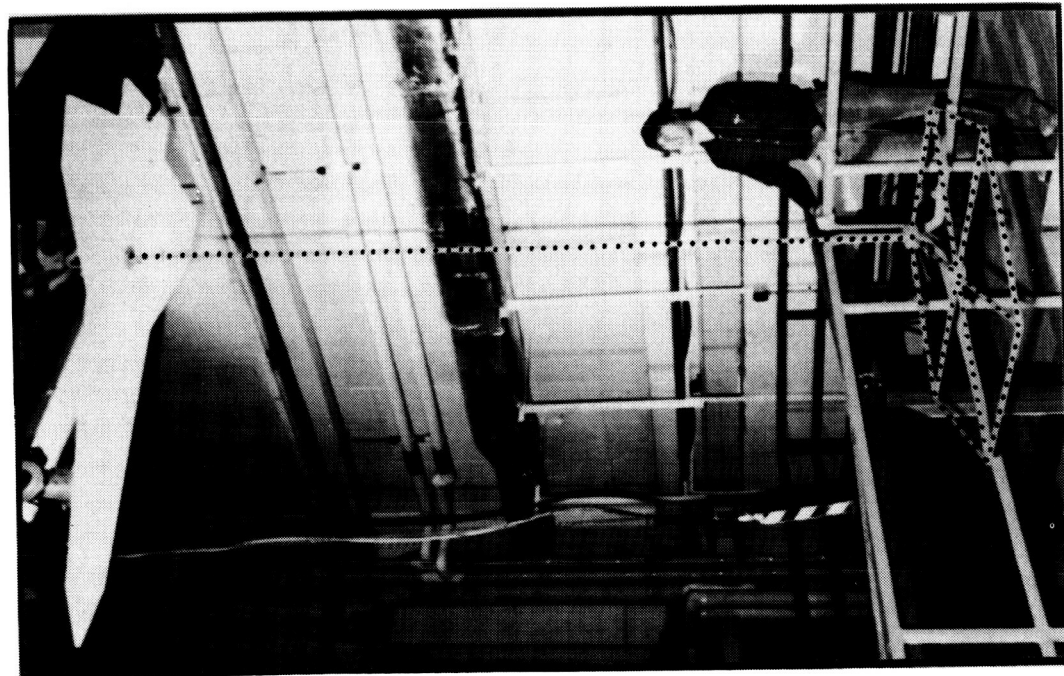
The Spacecraft Control Laboratory Experiment (SCOLE) will allow direct experimental comparison of competing control schemes for large flexible space structures. The experiment has been designed to emulate the essential characteristics of a mathematical model "design challenge" which represents a space shuttle having a flexible mast and antenna attached. This experiment is the third in a series of three flexible structure control experiments performed by the Flight Dynamics and Control Division at Langley Research Center. The key problem addressed by the experiment is that the flexible motion of the mast and antenna must be considered in the slewing and pointing control analyses.

The three dimensional control problem is facilitated by suspending the shuttle body from its c.g. by a three-degree-of-freedom ball joint on an eleven foot cable. This fixture allows free rotation about three axis and pseudo translation in the horizontal plane. The basic complement of control system components will be the same for all control schemes. This includes three-axis torque on the shuttle body, a pair of two-axis torquers on the mast, two-axis torque on the antenna end of the mast, and two-axis force at the center of the antenna. Sensors will consist of three-axis angular rate and linear acceleration on the shuttle body, five sets of two-axis accelerometers on the mast, three-axis angular rate at the antenna end of the mast, and two-axis acceleration at the center of the mast.

The computing system consists of a 32-bit microprocessor based CPU which is programmable in the C and Fortran languages. Data acquisition and actuator commands are accomplished with 12-bit analog-to-digital and digital-to-analog converters. Eight serial lines are also available to communicate with a distributed set of microcontrollers. These may be used to investigate "smart" sensor and actuator technology, or to perform some of the control law processing which would normally be done in the CPU.

TECHNICAL CONTACT: L. W. Taylor, LaRC, (804) 865-4591
J. P. Williams, LaRC, (804) 865-4591

SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE)



Provides mathematical and experimental
model for direct comparison of
competing control schemes

3-D Control
problem

Flexible modes in
control bandwidth

12 actuators
30 sensors
distributed computing

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SPATIAL, HIGH ACCURACY, POSITION-ENCODING SENSOR (SHAPES)

As space operations become more complex either because of increased size of spacecraft or increased number of spacecraft operating in a close proximity, more sophisticated control systems are required to maintain position and attitude, control vibration of extended structures and perform similar tasks. These, in turn, give rise to a need for sensors which can make rapid measurements of the three dimensional position of many points simultaneously at rates high enough for use by the control systems.

The SHAPES concept combines recent developments in fast laser diodes with established techniques in the areas of fiber optics, streak tubes, and CCD detectors into a system which measures the three-dimensional coordinates of many points distributed in space at rates high enough for control functions. A stream of pulses from a laser diode is directed to reflective targets and a fiber-optics delay line, which provides a coarse measure of the range. The fine measure of the range is provided by a comparison between the time of return of the pulses from the targets with the time of arrival of the pulses through the delay lines. This comparison is made with a streak image-converter tube whose output is detected by a CCD. Angular positioning of the targets is determined by a second CCD which detects the direct images of the target reflectors.

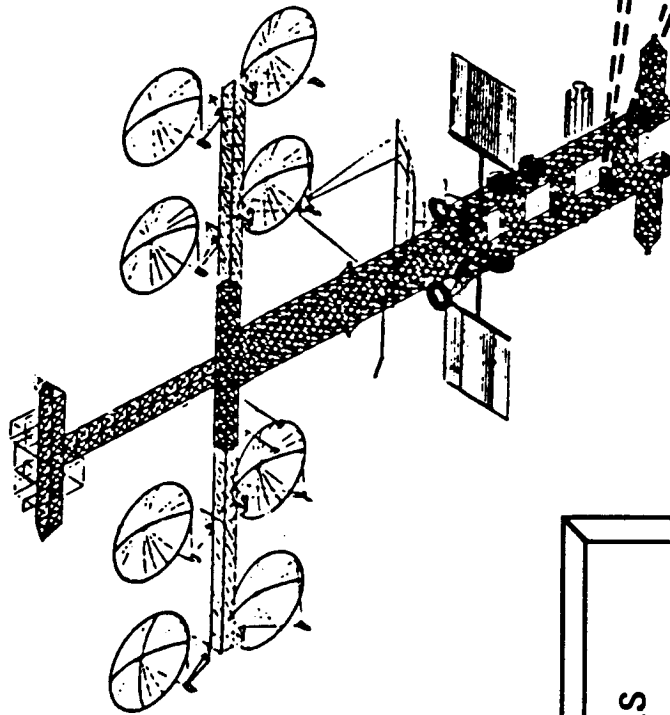
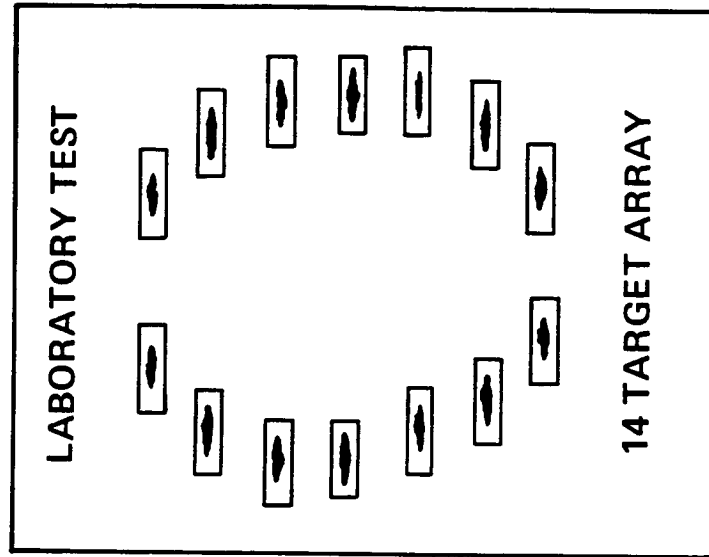
The expected performance of the SHAPES system can be summarized as follows. The accuracy of the angular measurement with full field optics is one part in ten thousand (10^4). With the addition of an "image combiner" of coherent fiber-optic bundles, this becomes approximately one part in one hundred thousand (10^5). The range measurement uncertainty is about 0.15 mm. The number of targets can be as high as 50 and the data range from 1 to 10 target sets per second.

Many of the technologies used in SHAPES are new. Some are more mature than others, but all are sufficiently mature to allow the development to proceed. Short-pulse operation of laser diodes has been demonstrated numerous times. The single mode fiber used in the delay lines was developed for optical communication and is commercially available. Streak tubes with picosecond resolution are available from several manufacturers, and CCDs have long been a commercial item and are available from several manufacturers.

A series of development experiments are underway, recently ranging to an array of 14 targets has been demonstrated. The facing illustration shows the output of the streak image-converter tube after processing by the computer. Each spot within a "window" is a return from a target. The location of the centroid of the spot on the CCD is a measure of the range increment to be added to the coarse range determined by the fiber delay.

TECHNICAL CONTACT: Eldred P. Tubbs, JPL, (818) 354-4058

ADVANCED GUIDANCE AND CONTROL COMPONENTS SHAPES: SPATIAL, HIGH-ACCURACY, POSITION-ENCODING SENSOR



ORIGINAL PROCESS
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CAPABILITY GOALS

50 TARGETS

1-200 meters RANGE

± 0.1 mm ACCURACY

SENSOR

SYSTEM IDENTIFICATION

The objective of this program is to develop a self-contained "suitcase" software module for potential "piggy-back" use on emerging large, flexible spacecraft, particularly the space station and space platforms. Control performance for these space systems will be sensitive to modeling errors such as truncated dynamics, parameter errors, neglected nonlinearities and sensor and actuator noise. Since these space systems are planned for assembly and growth on orbit, no ground test or a priori analysis can completely determine the effects of model error on performance or ensure that adequate control margins are designed to account for all dynamic affects during system lifetime. Analysis throughout the mission in the form of a ground data analysis function or in situ subsystem is then needed to monitor control performance during dynamic disturbance or system change. Through this procedure, parameters which adapt controllers to account for the new environment can be determined.

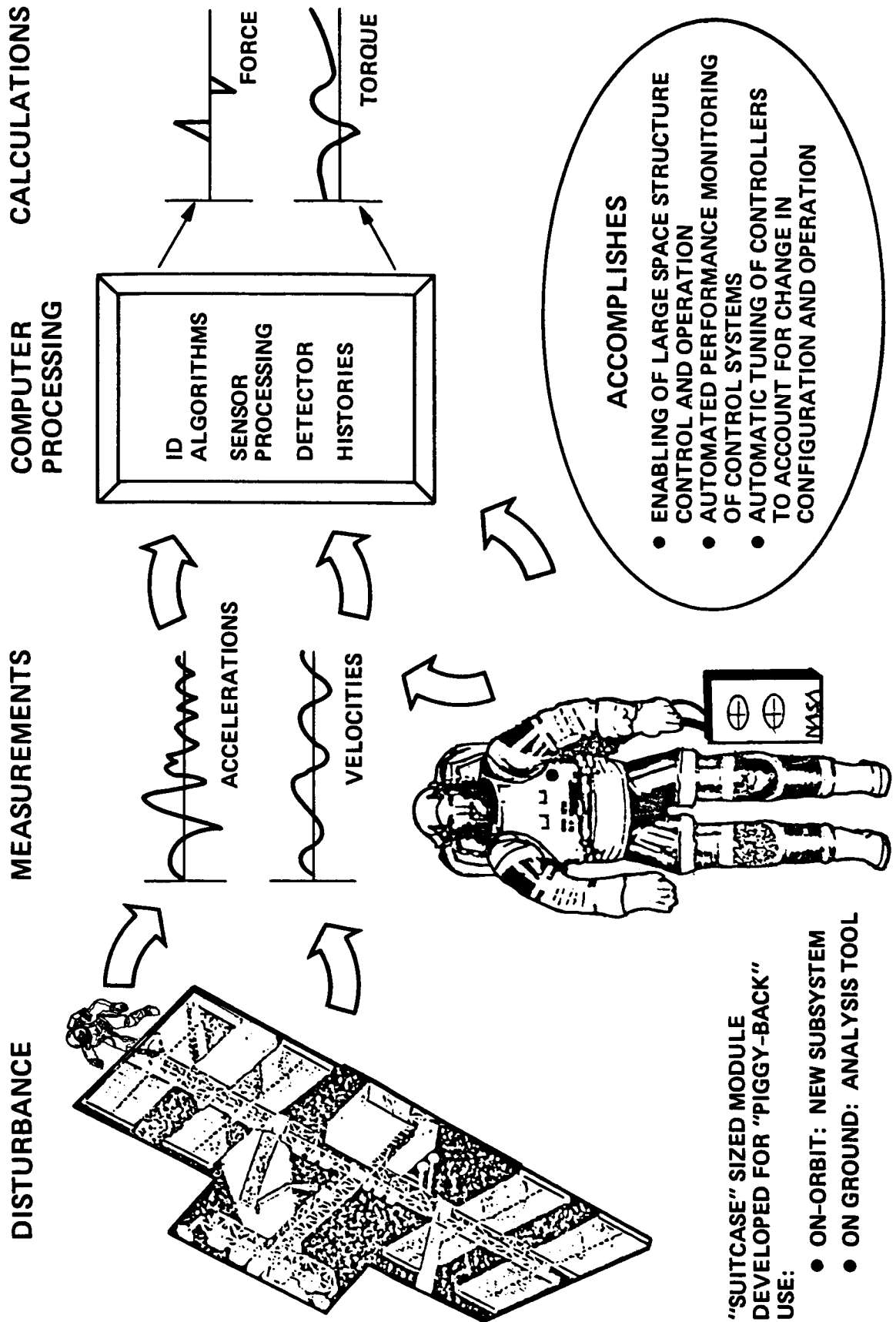
The task is broad in scope and developments are required in synthesis of flight-qualified subsystem level ID capability, fast algorithms for handling large scale models and vast amounts of data, strategies for sensing, data collection and processing, and end architectures which accommodate parallel processing and autonomy. As the example of crude disturbance identification indicates, technologies in these areas must be integrated in the performance of an identification function.

80

Activities in FY 1984 focused on the development of a new approach for fast filtering, smoothing, and identification for spatially distributed systems; a proof-of-principle evaluation with typical large space station and antenna models; the definition of a potential early-technology demo targeted to planetary spacecraft; and the development of integrated software system functional requirements. Future work will involve evaluation of identification algorithms in application to space station through extensive ground simulation and proof-of-principle experiments with physical models. Results of these activities will be used in the development of the requirements and architecture of the software module.

TECHNICAL CONTACT: Fernando Tollivar, JPL, (818) 354-6215

SPACE STATION SYSTEM IDENTIFICATION

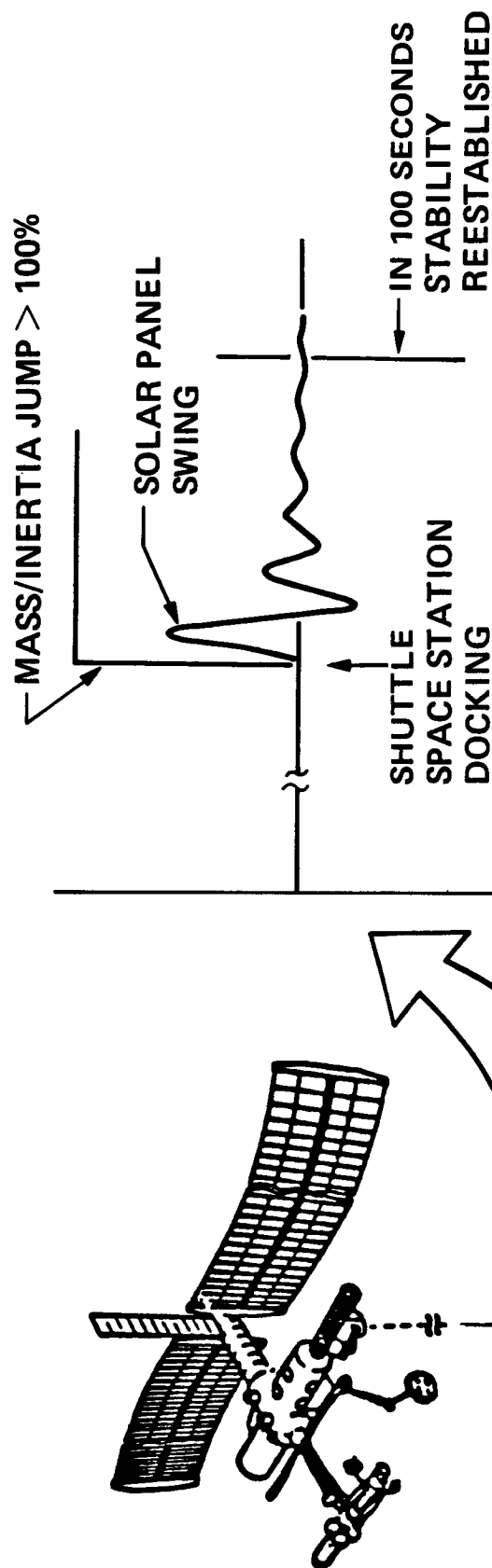


ADAPTIVE CONTROL SUBSYSTEM AUTOMATION

The objectives of adaptive control technology are to develop autonomous systems capable of compensating for poorly known and truncated dynamics, time-varying plants and environments, and large disturbances due to growth and failures. Progress in FY 1984 consisted of the development of an adaptive controller with inner-loop plant augmentation; simulations for time-varying plants, shuttle docking dynamic, and a model reference adaptive controller; implementation of methods for control effort reduction with model switching and disturbance modeling; and evaluation of actuator saturation and hardware constraints. Future work will continue to address the areas of practical constraints in order to qualify the technology for integrated flight system implementation.

TECHNICAL CONTACT: Fernando Tolivar, JPL, (818) 354-6215

AUTOMATED ADAPTIVE CONTROL SUBSYSTEM



ACCOMPLISHMENT

SYNTHESIZED AND ANALYTICALLY
TESTED A ROBUST ADAPTIVE ATTITUDE
CONTROL ALGORITHM FOR DOCKING
OF LARGE SPACE VEHICLES

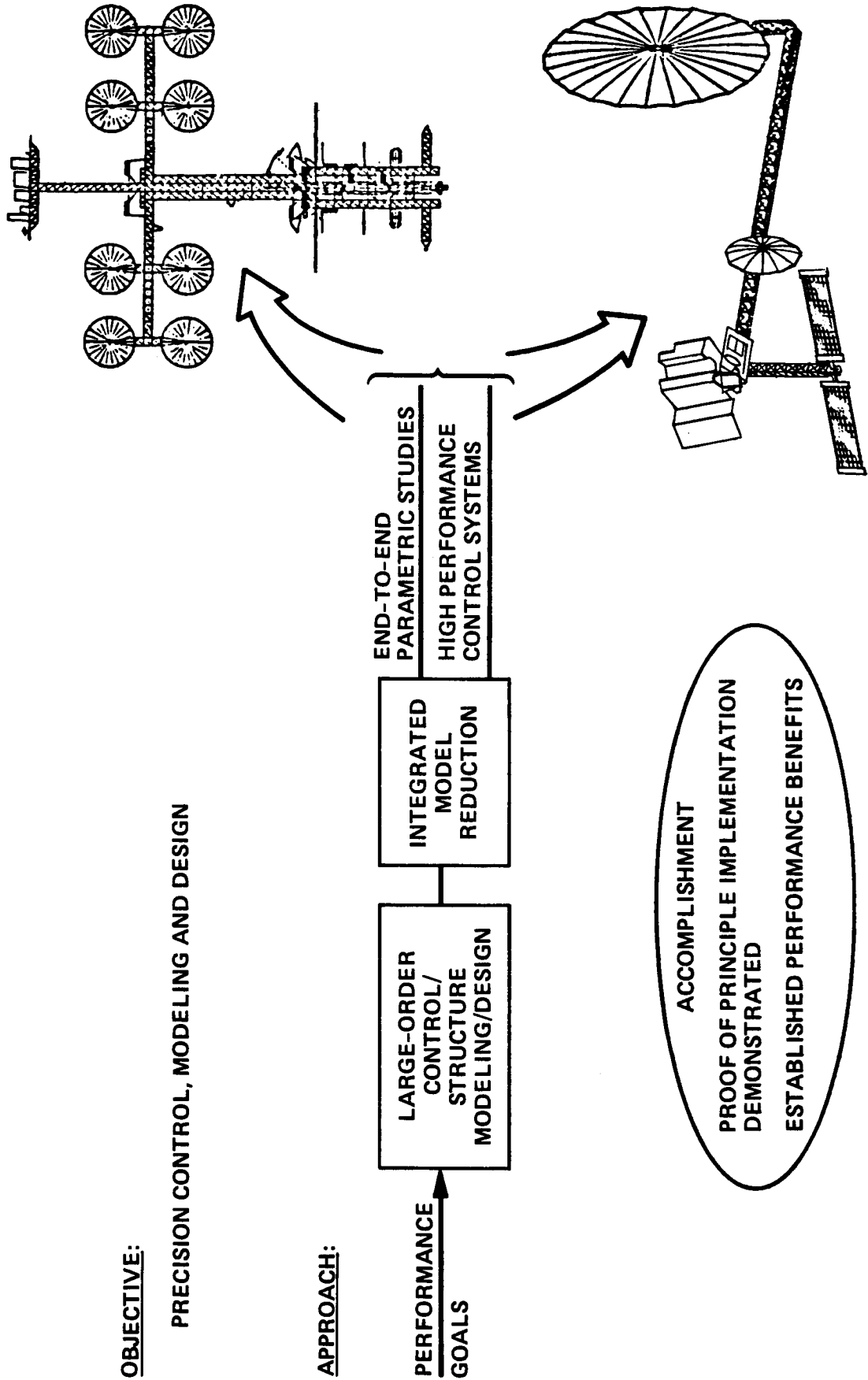
UNIFIED CONTROL STRUCTURE MODELING AND DESIGN

The long range program objective is to develop an integrated control/structure design methodology that synthesizes results and procedures from distributed system theory, control-driven structure optimization and finite-element modeling, closed-loop model-order reduction methodologies, and robust frequency domain methods. This new design capability will eliminate drawbacks of current design approaches where: structural models are independent of control objectives; model order selection is an ad-hoc process; simplified design models are difficult to obtain; and system level closed-loop studies become prohibitive. The projected benefits are finite-element models will be driven by system requirements; end-to-end model truncation and parametric studies can be readily conducted; and spillover instabilities will be reduced.

The key challenge is that software to assemble control-driven finite-element models for complicated structures does not currently exist. The progress in FY 1984 consisted of the initial development of the unified structural modeling and control design method together with a proof-of-principle implementation demo, and demonstration of performance benefits over current approaches. In addition, a NASA/JPL/LaRC workshop on identification and control was held jointly with the 1984 American Control Conference and included Jet International participants from industry, universities, and research laboratories.

TECHNICAL CONTACT: Mark Milman, JPL, (818) 354-7548

UNIFIED CONTROL, MODELING AND DESIGN



NONLINEAR DYNAMIC MODELING

Nonlinear dynamic modeling is effected by a software program called TREETOPS. TREETOPS (Tree Topology) refers to the class of structures that may be simulated by the program. TREETOPS is a time history simulation of the motion of a complex multibody flexible structure in a tree topology with active control elements. This simulation offers the user an advanced capability for analyzing the dynamics and control-related issues of complex flexible structures.

TREETOPS is based on a unique formulation of the differential equations of multibody flexible structures. The formulation is based on a floating reference frame for the elastic deformation, which gives good convergence to the system mode. Furthermore, by using the augmented modes of the individual bodies, convergence is achieved using fewer individual body modes. As a result, the kinematic variable count is kept low and the computational requirements are reduced.

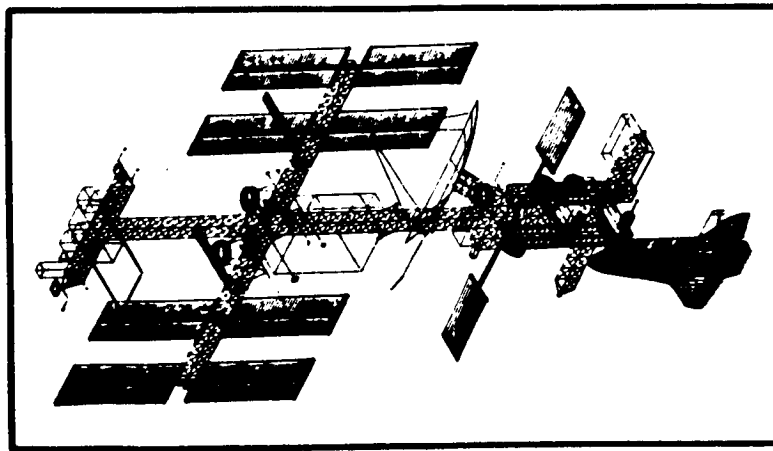
TREETOPS offers a further advantage in that the modal characteristics of the total structure need not be determined. The total structure is thought of as an interconnected set of individual bodies. Each individual body is described by its own modal characteristics with prescribed boundary conditions. Thus, the costly step-by-step modal analysis of the composite structure for each incremental position change is eliminated.

TREETOPS is intended as a control system and analysis tool for complex multibody structures in a tree topology. Since the dynamic equations have been formulated and programmed in a general sense, the user need not be a dynamics specialist. The simulation also has an interactive set-up program that is easy to use; it creates all the necessary data files so the user need not be a FORTRAN programming expert. These two features, along with the computational efficiency achieved with fewer modes, make TREETOPS a very useful control system analysis tool.

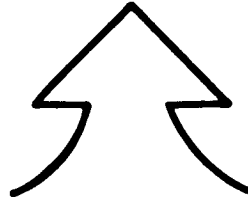
The TREETOPS software package is ideally suited for the Space Station configuration. The Tree Topology for the Space Station is composed of 15 flexible bodies in which some of the bodies have large angular motions (solar panel). Once the flexible body data are fed to the TREETOPS program, the control design engineer can use the program's linearization option to determine the mass, damping, stiffness and control input matrices. These matrices are needed for the control system design. After the control system design has been effected, then the TREETOPS program can simulate the nonlinear dynamics and control model of the Space Station so that control performance can be evaluated.

TECHNICAL CONTACT: Harry Buchanan, MSFC, (205) 453-4582

NON LINEAR MODELING

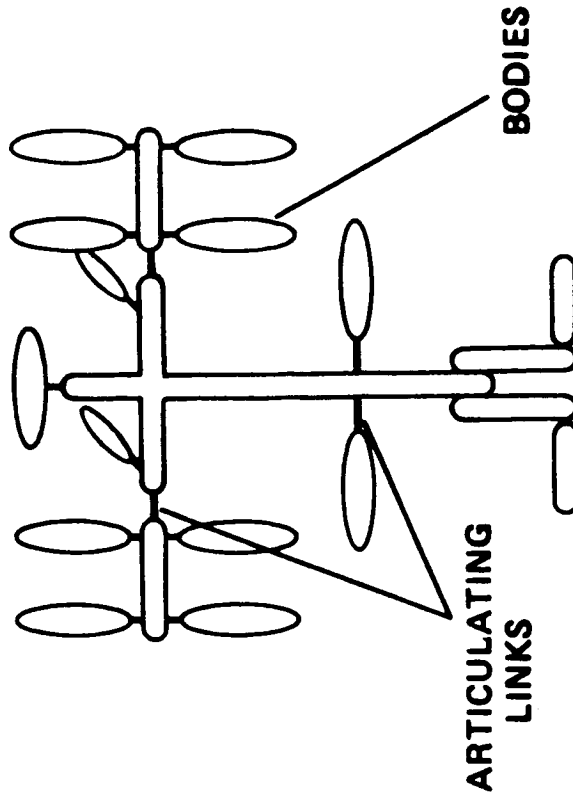


- TOOL DEVELOPED FOR EFFICIENT MODELING OF ARBITRARY AND CHANGING CONFIGURATIONS



SIGNIFICANCE

- FEWER MODELING AND ANALYSIS MANHOURS
- FASTER RESPONSE TO ANALYSIS REQUESTS
- ABILITY TO MODEL ARTICULATED STRUCTURES (LARGE ANGLES)



TREE TOPOLOGY
(15 BODIES)

FIBER OPTIC ROTATION SENSOR (FORS)

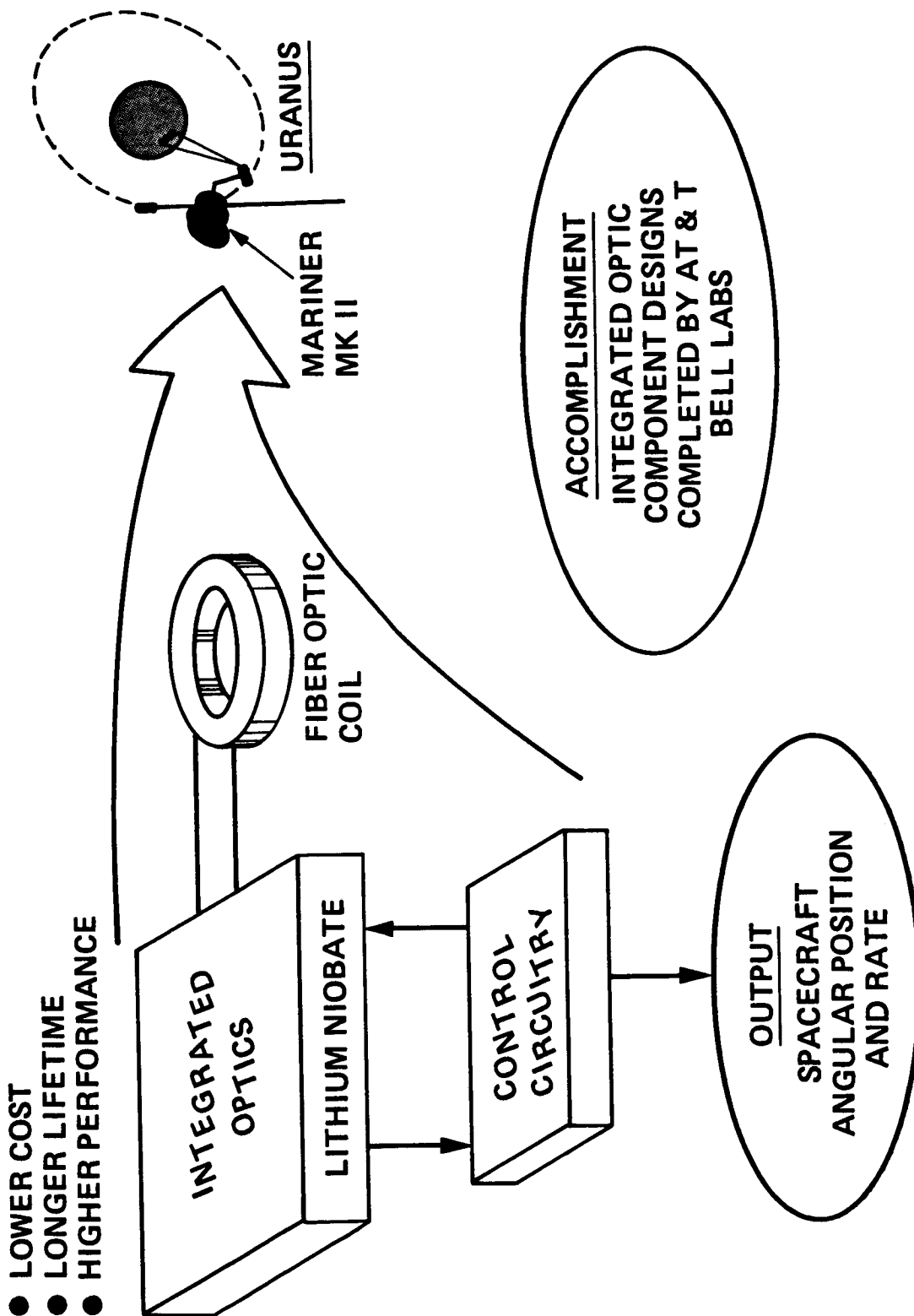
The objective of this task is to develop a 10 year lifetime, low cost, navigation-grade optical gyroscope using semiconductor lasers, fiber optic waveguides, and integrated optical waveguide circuits.

A contract was placed with AT&T Bell Labs in May, 1984, for the integrated optics. All of the 1.3 micron components (switches, polarizing beam splitters, phase modulators) and the fiber attachment process have been previously demonstrated at AT&T. The present contract will demonstrate consistent component performance for a single common processing schedule.

An advanced optical circuit, recently conceived, will now perform all the key signal processing functions. This design has a closed loop phase control which will allow operation over a very wide range of rotation rates. The output signal is in the form of incremental position angle and "beats" like a ring laser gyro (RLG). There is no scale factor non-linearity at null, which is a problem with the RLG. The optical circuit fits on a 5 cm long chip and occupies a width of about 250 microns.

TECHNICAL CONTACT: W. Goss, JPL, (818) 354-4455

FIBER OPTIC ROTATION SENSOR



STS GUIDANCE AND CONTROL

Operational experience in orbital deployment and manipulation of payloads of various sizes using the Orbiter indicates the need to reduce the sensitivity of the control system to changes in the combined Orbiter/payload mass/inertia properties and center of gravity location. Present control system technology, as reflected in the Orbiter design, is limited in the range of these properties that can be accommodated without costly and time consuming software changes. Also, the requirement to ensure adequate stability and efficient performance with vastly different payload mass/inertia properties results in a relatively long-term, sustaining engineering force during the operational phase. This requirement thus assures payload/flight control system (FCS) compatibility on a mission-by-mission basis. Advanced vehicles such as Space Station will entail much larger changes in plant characteristics during build-up, with larger uncertainties than ever before.

The JSC has initiated a technology advancement program to develop the requirements and perform a typical FCS design that is inherently adaptive to large variations and uncertainties in mass/inertia properties, control effector configuration, and external disturbances such as aero and gravity gradient torques. The approach is as follows: to investigate methodologies to reduce the potential for dynamic interaction within an Orbiter-type digital autopilot; to determine the expected variations and uncertainties of the driving parameters for future vehicles; to develop new methods for providing traceability of design driving requirements through all levels of software and design implementation documentation; and finally to apply the resulting design concept improvements to a control system design problem for a typical large, flexible spacecraft. This requires four specific study areas: (1) definition of the limits of the present control envelope, (2) development of a new method for software requirements documentation and control, (3) definition of the scope of the requirement for adaptive control through long-range planning studies, and (4) development of requirements and software models for a large vehicle control system that is autonomously adaptive to all rigid body and external disturbance parameters.

Parametric analysis of the Orbiter control system indicates several areas of design that could significantly improve stability, e.g., replacement of the inertial maneuvering unit rotational state estimator with ideal rate gyro information could provide dramatic improvement in stability and performance. As a result, consideration will be given to integrating the existing rate gyros (sized for ascent and entry) into the on-orbit control system. Several software improvement concepts were investigated, including a new automatic maneuver routine algorithm which will be evaluated with system uncertainties.

Long range planning studies have addressed the need for improved on-orbit control systems. As a result, a major effort is underway to implement the NASA inter-center-sponsored workshop on rendezvous and proximity operations to be held early in 1985.

TECHNICAL CONTACT: Paul C. Kramer, JSC, (713) 483-3254

STS GUIDANCE AND CONTROL

- RIGID BODY
- SMALL CG TRAVEL

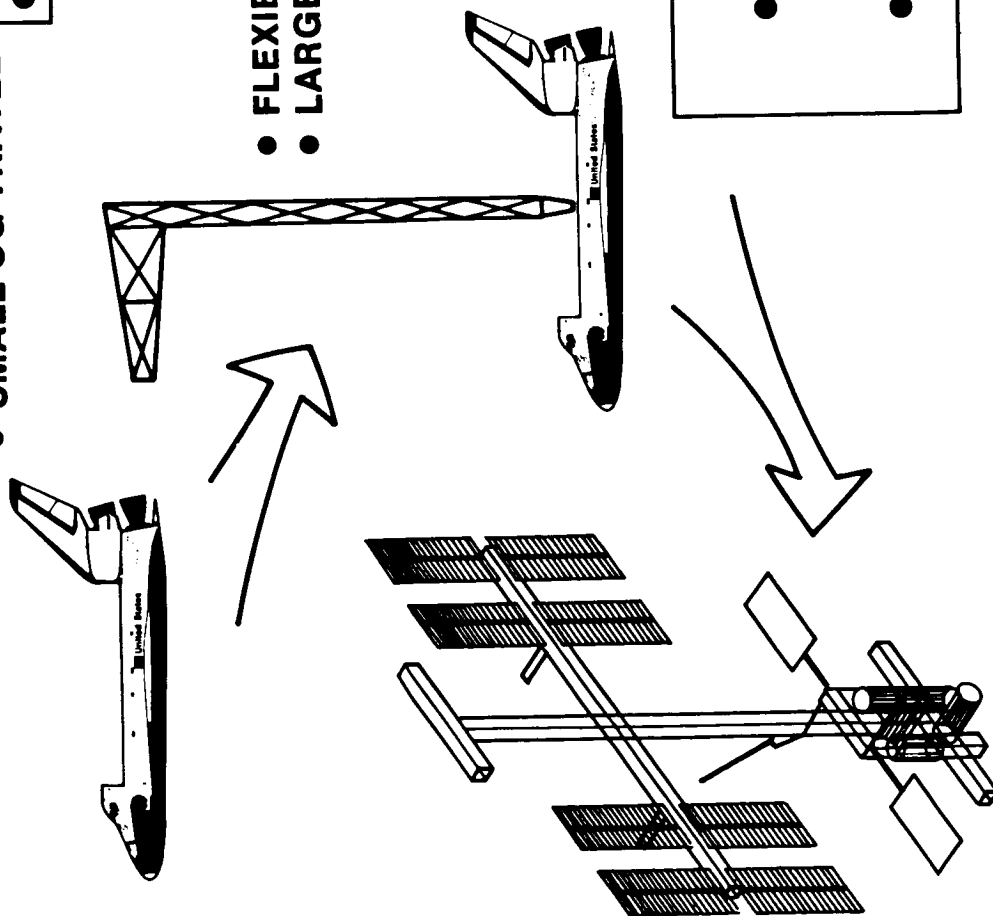
ACCOMPLISHMENTS

- CONFIGURATIONS DEFINED
- THREE CONTROL SYSTEMS STUDIED

- FLEXIBLE APPENDAGES
- LARGER CG TRAVEL

PAYOFF

- SINGLE CONTROL SYSTEM:
 - STABILIZES LARGE FLEX BODY
 - BUILDS UP STATION
- REDUCED SOFTWARE COSTS



C-2

AUTOMATIC DOCKING TECHNOLOGY

Spacecraft docking techniques currently used by NASA rely on a human operator, who uses visual and other cues to fly the chase spacecraft into position to capture the target spacecraft. In the case of Gemini, Apollo and the Manned Maneuvering Unit, the operator was a pilot actually on board. For the Orbital Maneuvering Vehicle, an operator will fly the vehicle remotely using a TV image. If this teleoperation approach were replaced with a fully automated scheme, better and more reliable performance could result.

Over the past five years, several automated docking approaches have been explored in computer simulations and small scale tests. Several schemes for sensing relative position and attitude errors have been examined. Current plans call for the large scale demonstration of the most promising of these techniques in a hardware simulation at MSFC. This demonstration will utilize the large air bearing floor (opposite page). An optical sensor utilizing star tracker technology will be used to image a pattern of lights on a target spacecraft mock-up. From analysis of this apparent pattern, target orientation and range can be extracted using algorithms developed for this purpose. Relative position and attitude errors can then be used to drive a terminal guidance scheme which will fire thrusters on the test vehicle moving over the floor, causing it to move into alignment with the target vehicle.

The concept described has been the subject of extensive computer simulations which have demonstrated feasibility. The current exercise would take this a step further by demonstrating the concept with actual hardware in a realistic environment. While the sensor head and control processor used in this application would not be suitable for flight, the design and requirements developed could be the basis for an automatic docking kit which could be developed and flown on the Orbital Maneuvering Vehicle.

TECHNICAL CONTACT: Harry Buchanan, MSFC, (205) 453-4582

AUTOMATIC DOCKING

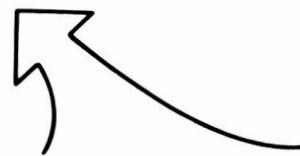
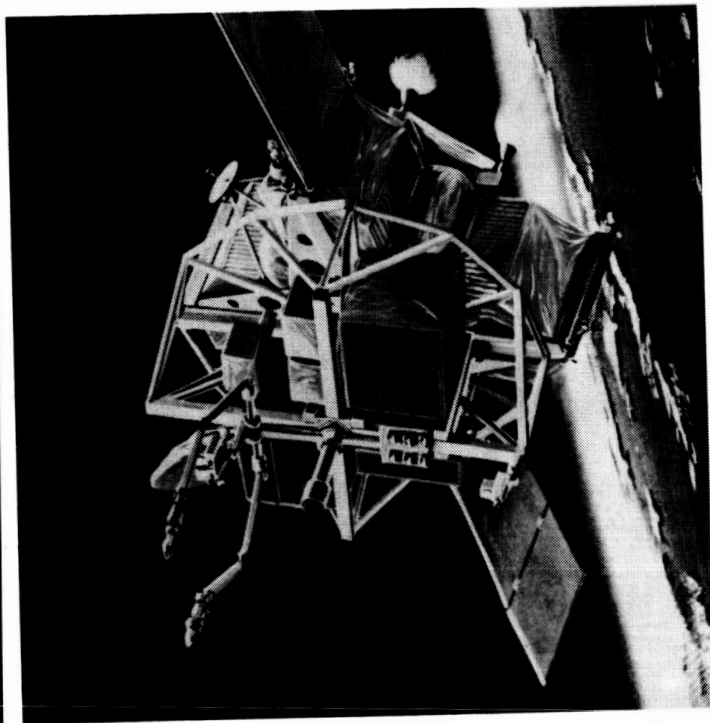
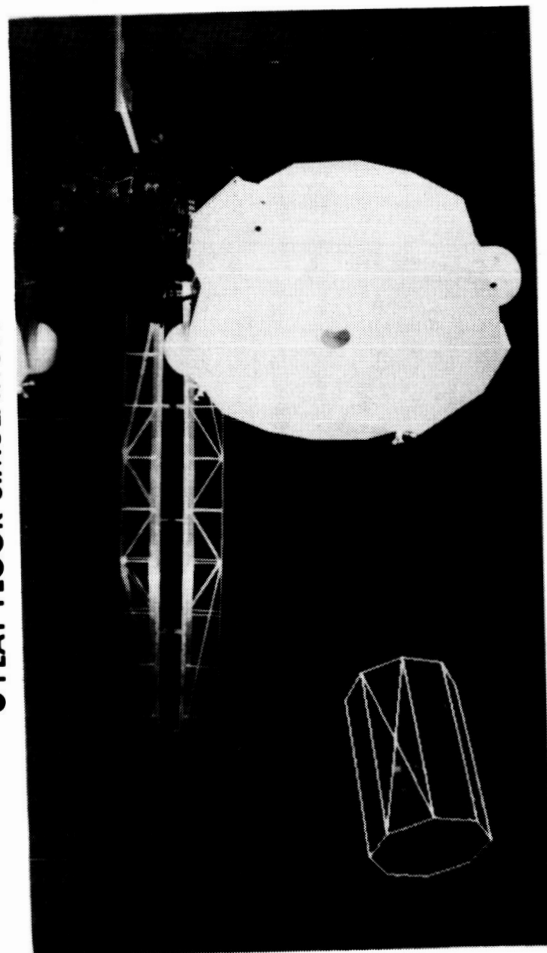
● TRADED LASER, R. F.,
AND VIDEO DOCKING



● SELECTED VIDEO
CONCEPT FOR HARDWARE
DEMONSTRATION



● FLAT FLOOR SIMULATION



CONSTRUCTION/DOCKING TECHNOLOGY

Future space activities will require a broad capability for docking and berthing many types and sizes of spacecraft, space structures and payloads. Some of these will require a capability for very low energy docking and berthing. These linkups will be for functions such as assembly of large structures, crew and equipment transfer, inspection and servicing.

The primary objective of this task is to develop the required technology for soft docking and berthing by designing, developing and testing a prototype full-scale docking/berthing interface mechanism. Components of the system are being developed in the Mechanical Systems ("smart mechanisms") Lab at JSC, and the total system prototype will be tested in the JSC Docking Test Facility (opposite page).

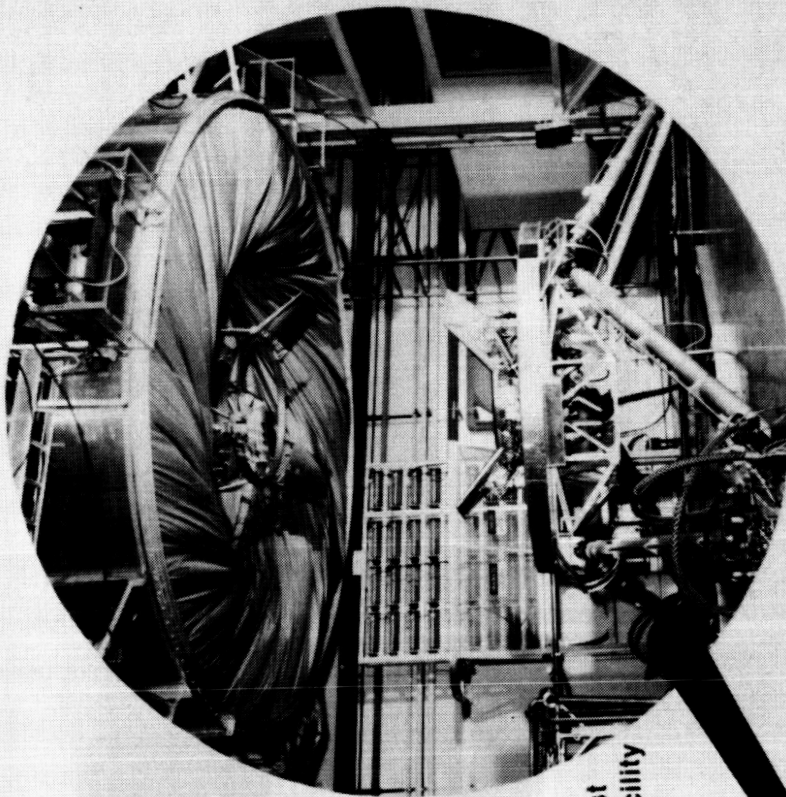
The general approach to this task includes requirements definition, design, analysis and prototype testing. Future program requirements are used to define the design requirements as an ongoing activity. Based on these requirements and conceptual designs, detailed designs of selected prototypes are produced. Parametric trade studies are also performed to refine the designs and to identify design drivers. Component technology development includes microcomputer-controlled actuator/attenuator devices. Full-scale developmental systems will be fabricated and "proof-of-concept" ground tests performed.

The primary activity during FY 84 has been to continue design of the man-transfer docking/berthing system using the approach described above. This "point design" effort is based on an androgynous interface with a clear opening to allow crew and cargo transfer. The requirement for an unobstructed passage, i.e., no mechanisms can be removed to clear the passageway, is fundamental to the design approach that is at work. The design includes a combination capture/structural latch to attach the two mating interfaces; the detailed design of this mechanism is nearly complete. A prototype latch will be built for component testing.

A related activity, initiated in FY 84, is a study of the dynamics associated with berthing a large payload, e.g., the proposed Industrial Space Facility, with a berthing module located in the Orbiter payload bay.

TECHNICAL CONTACT: W. K. Creasy, JSC, (713) 483-2561

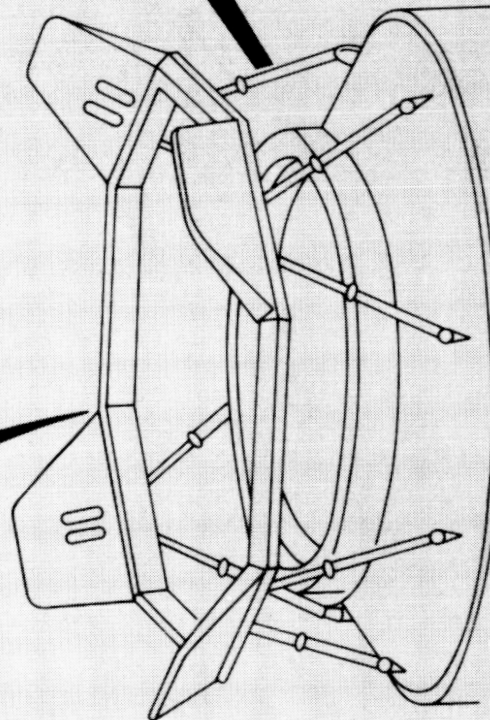
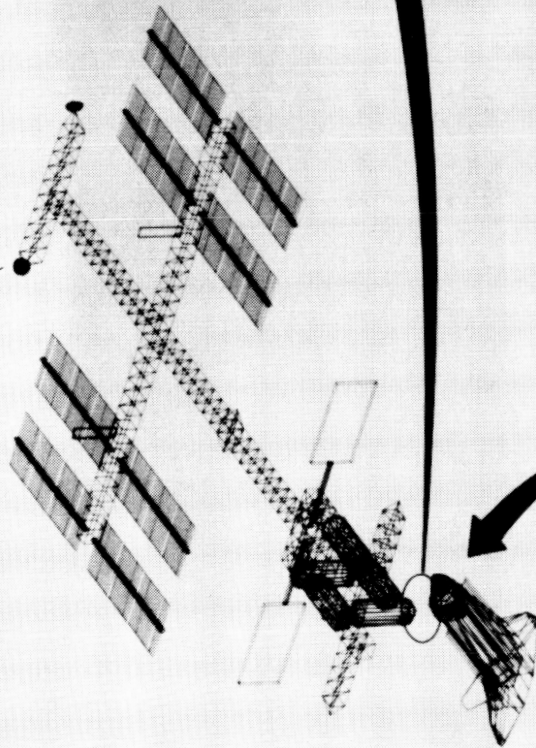
Construction/Docking Technology



Test
Facility

Accomplishments

- Conceptual Designs for Space Station Docking and Berthing
- Prototype Electromechanical Actuator/Attenuator in Test
- Buildup and Utilization of "Smart Mechanisms" Laboratory



Docking/Berthing Mechanism

ADVANCED AUTOPILOT FOR SPACECRAFT (AAPS)

The program objective is the design, development and flight demonstration of the operational benefits of an advanced autopilot for control of on-orbit spacecraft.

Currently, autopilots provide inefficient control solutions due to axis-by-axis control laws, separate solutions to rotation and translation control requests and precalculated jet selection tables. This results in excessive fuel consumption and increased thruster operation creating long term maintenance problems. The Advanced Autopilot provides an efficient, integrated solution to these problems through a six-dimensional phase space control law which provides a combined solution to rotational and translational commands and calculates fuel-optimal jet selections and firing durations.

The Advanced Autopilot has been developed and incorporated into the Space Shuttle on-orbit software. It's first flight test is scheduled for STS 51-G during the second half of calendar year 1985. The expected benefits of this project are to provide an autopilot which is more fuel efficient, maximally tolerant to reaction jet failures and easily adaptable for use on other spacecraft.

TECHNICAL CONTACT: Ed Chevers, JSC, (713) 483-2851

STS ADVANCED AUTOPILOT

ATTRIBUTES

- OPTIMAL FUEL CONSUMPTION
- ADAPTS TO MASS PROPERTY CHANGES
- RECONFIGURES FOR FAILED JETS



SIX DIMENSION
PHASE SPACE CONTROL
WITH ADVANCED AUTOPILOT

AXIS BY AXIS
CONTROL WITH
EXISTING ORBITER
AUTOPILOT

ACHIEVEMENTS

- AUTOPILOT CODED AND VERIFIED
- INCLUDED IN ORBITER OI-6 FLIGHT SOFTWARE BUILD
- SCHEDULED FOR USE ON FLIGHT 51-G

DATA SYSTEMS

The objective of the Data Systems Program is to provide the technology needed to enable more cost effective space-derived information, to substantially increase the capability of on-board and ground processing and to provide the computational systems necessary for the evolutionary space station.

In 1984, the optical disk recorder was completed and delivered to MSFC for incorporation into the Space Plasma Physics Network. The unit provides an on-line storage capacity of ten trillion bits. The data transfer rate of the unit is 50 million bits/second. The system will automatically catalog and archive data packets to support on-line users. The first non-DOD Very High Speed Integrated Circuit (VHSIC) technology insertion study was started in 1984 by LaRC and JPL. The target of a ten fold increase in on-board general purpose computing capability will be available for the initial Space Station configuration. The design and layout of a GaAs on-board processor was completed in 1984. The GaAs processor can provide a substantial increase in performance at a reduced power level.

The advanced development of a ground/on-board Tera-bit very high data rate optical disk buffer unit was initiated. This program is a joint effort with other government agencies, and will provide the capability to rate buffer sensor data of greater than one Giga-bit/sec for transmission at lower data rates. When the buffer and the VHSIC array or general purpose processors are combined, an on-board quick look capability for data importance can be implemented to achieve a substantial reduction in transmission bandwidth.

PROGRAM MANAGER: Kenneth Wallgren
NASA/OAST/RC
Washington, DC 20546
(202) 453-2868

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VHSIC TECHNOLOGY FOR SPACE APPLICATIONS

Major system advantages for implementing new designs in the VHSIC technology were identified by NASA during FY 1984. Early insertion opportunities were identified within space station IOC (as embeddable processors), within OSSA (as free flying processors) as well as within Langley and Ames mission sets. Studies indicated that significant enhancements in fault tolerance at the system level could be achieved by use of chip level, built-in-tests used by all the VHSIC contractors. Modeling to demonstrate these advantages to the proposed systems is in progress.

Many DoD VHSIC contractors have demonstrated large numbers of successful chips, indicating the status of this technology. Some also have operational brassboards, indicating a readiness for mission insertion.

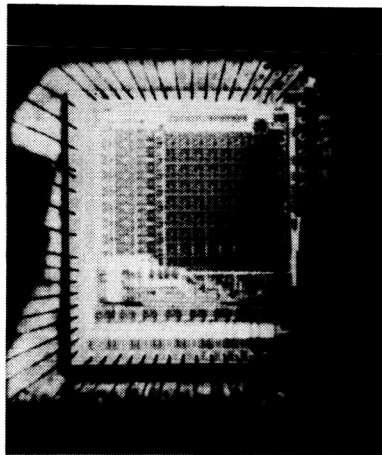
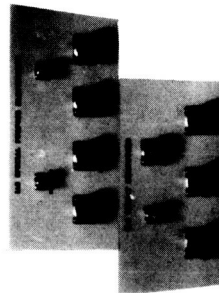
Space station modeling is expected to be completed, thereby identifying the levels of fault tolerance achievable for architectural types, as well as candidates for IOC scarring for evolutionary upgrades. Initial OSSA, LaRC, and ARC mission set insertion candidates should be identified and planning for insertion commenced. The network and fiber optic interface will be completely defined and implementation will begin.

TECHNICAL CONTACT: David Smith, JPL, (818) 354-4480
Harry Benz, LaRC, (804) 865-3535

VERY HIGH SPEED INTEGRATED CIRCUIT VHSIC TECHNOLOGY

EXISTING

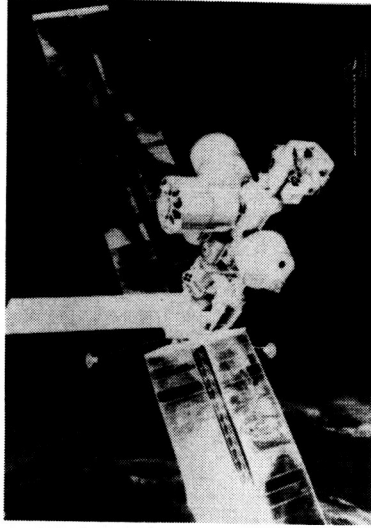
- < 1 MOPS
-



VHSIC

- FAULT TOLERANT
- > 3 MOPS
- ADA LANGUAGE

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PAYOFF

- SIZE, WEIGHT, POWER, RELIABILITY
- STANDARD TECHNOLOGY

ADVANCED DISTRIBUTED SYSTEM NETWORKS

The emphasis of this task is on developing a network simulation capability and a fiber optics technology characterization capability at ARC for evaluating advanced spaceborne data network designs applicable to the local area network (LAN) needs of the Space Station. Previously, the program had been focused on R&D issues at the physical and data link layers of the OSI reference model, but is now expanding to cover higher layer issues as the technology base expands. The data network simulator under development may be used agency-wide for design trade-off studies.

A major benefit of this software development effort will be the ability to specify sophisticated load characterizations of data traffic at nodes in a Space Station LAN. This capability will fill a gap in a network research area that currently lacks good support tools and will aid in NASA/user community communication. Another benefit will be to enable early identification of crucial LAN performance and reliability characteristics based on design decisions made at the hardware level such as transceiver design, signal coding techniques, and network topology. Likewise, various software implemented protocols will be studied to evaluate their impact on network performance and reliability.

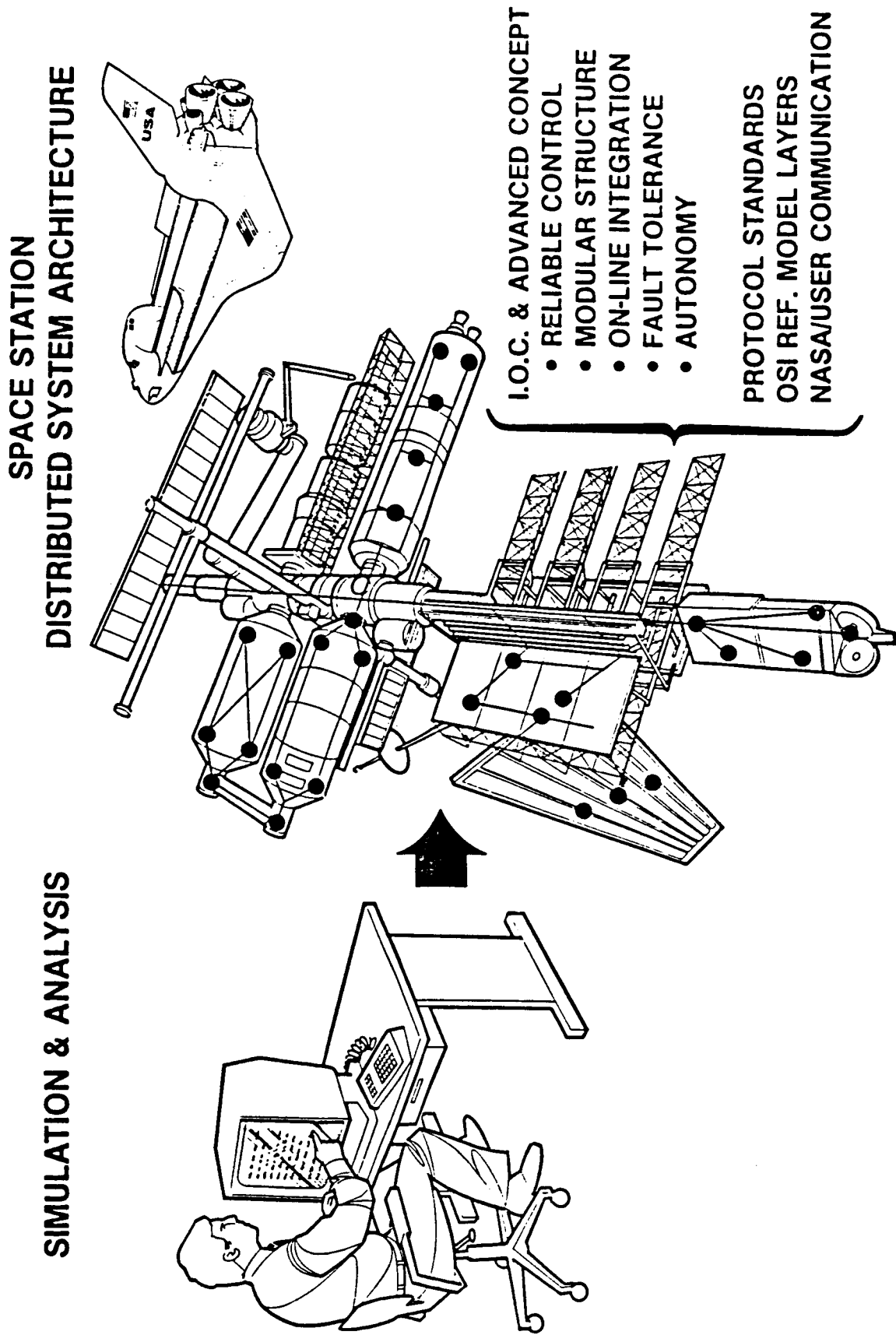
A functional specification for the LAN simulator, LANES, has been produced and reviewed by an inter-center working group. A prototype simulator has been used to work out the user interface, and the first production version has been released which provides R&D support for the GSFC Fiber Optic Demonstration System. Two successful remote demonstrations of the simulation at contractor sites have illustrated its utility.

The simulator is being extended to provide additional topologies and data link layer models as well as to support in-house studies of issues such as techniques for on-line integration of new nodes, reliability and fault tolerance concepts and automatic data flow control. The simulation is being complemented with queueing theory analyses of similar models to establish bounds on performance and to help validate the results.

Research has been started to characterize and model distributed system architectures and implementations with the aim of better integrating computer operating systems and networking subsystems. The potential benefits will be improved performance, smaller maintenance problems, flexibility to expand capability and higher reliability. A survey report on network reliability issues for the Space Station has been completed.

TECHNICAL CONTACT: Terry L. Grant, ARC, (415) 694-6526

ADVANCED DISTRIBUTED SYSTEM NETWORKS



INFORMATION NETWORK ARCHITECTURES

Information data systems are needed for advanced aerospace missions, such as space station and its co-orbiting platforms, that are evolvable, adaptive, and fault tolerant. Local area information networks are considered a likely technology solution; their principle needs are: (1) improved information flow between devices on a network and its control, particularly for moderately or tightly coupled, high performance processes; (2) network fault tolerant properties capable of meeting safety related criticalities; and (3) high performance (>100 Mbps), to accommodate space station requirements for an integrated system data network from where video, voice, and data are to be simultaneously accommodated.

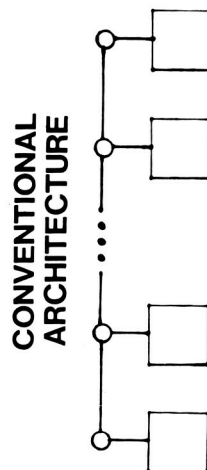
The braided mesh form of network helps meet the above needs with the following features: (1) simultaneous adaptable data communication links offer dynamic and high performance accommodation, and (2) alternate communication links provide a capability for self-correcting and repairing (or fault tolerant) properties. Also, the high performance requirement leads to the concept of a network that uses fiber optics links and optical nodes, fiber optics with wavelength division multiplexing would likely be used.

The objective of this activity is to research and characterize the architectural issues of the braided mesh form of network. The technical thrust is to develop an optical mode which would form the user interface into the network, control user access to the network, provide adaptable multiple path data communications from/to other nodes and provide for overall control of the network. A means of low loss optical switching is currently being developed through the use of integrated optics. The recent state of optical technology suggests that a first generation optical node will be a hybrid optoelectronic device in which the switching will be optical, but the logic and control signals will be electronic. Future generations of the node would become more optically configured as optical processing capabilities improve.

TECHNICAL CONTACT: Nick Murray, LaRC, (804) 865-3535

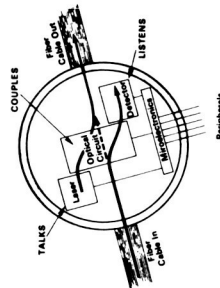
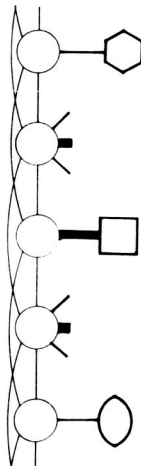
INFORMATION NETWORK ARCHITECTURES

TECHNOLOGY LIMITATIONS

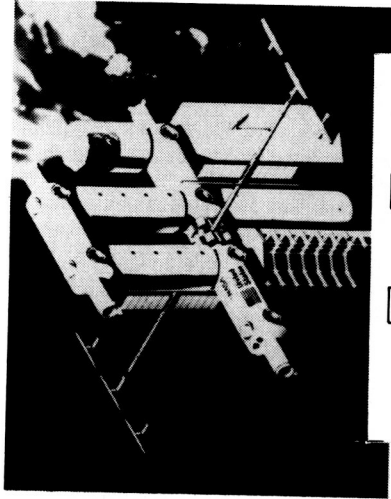


- PURELY PASSIVE SWITCHES
- INFORMATION "BOTTLENECK" FLOW
- SUSCEPTABLE TO SINGLE POINT NODE FAILURES
- REDUNDANT SUBSYSTEMS REQUIRED

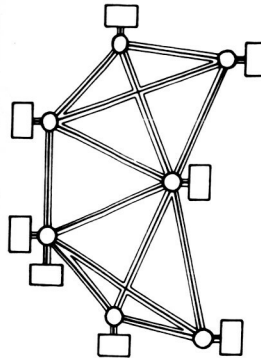
MESH NETWORK AND OPTICAL NODE TECHNOLOGY



- OPTICAL MESH NETWORK EMULATION
- HYBRID OPTICAL / ELECTRONIC NODE DEVELOPMENT
- INITIATED COMPONENT DEVELOPMENT
- MODEL/EVALUATE NETWORK FLOW EFFICIENCY



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PROGRAM PAYOFF

- PROVIDES INTEGRATED/
GROWABLE INFORMATION
SYSTEMS NETWORK
 - DATA MANAGEMENT
 - COMMUNICATIONS
- IMPROVES CAPACITY & SPEED
OF INFORMATION FLOW
- MAXIMIZES DEGREE OF FAULT
TOLERANCE

ADVANCED DIGITAL SAR PROCESSOR (ADSP)

The ADSP is being developed to demonstrate the technology required to meet the SAR data processing requirements of missions in the late 1980s. An engineering model will be built and demonstrated using SIR-B data in early FY 86.

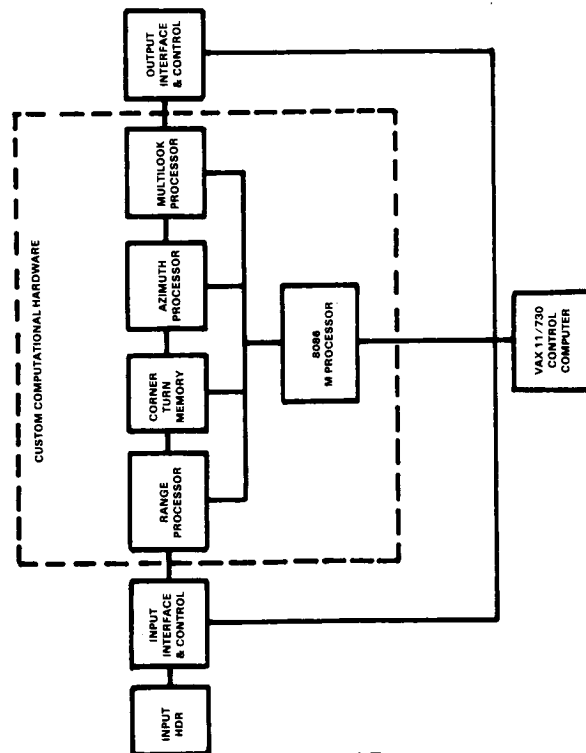
The algorithm used for both range and azimuth processing is the FFT convolution implemented in a pipeline architecture (as shown in the system diagram). The design will accommodate processing of at least 1/4 swath of the SIR-B data at real-time rates. Computational capability is in excess of 1.4 x 10⁹ floating point operations per second with a dynamic range in excess of 100 dB.

The range correlation was completed and tested during FY 84; the computational rate for the correlation is equivalent to 1400 M FLOPS. The one dimensional FFT unit is capable of processing a 20 MHz continuous data rate. Design and fabrication of the azimuth correlation is planned for FY 85.

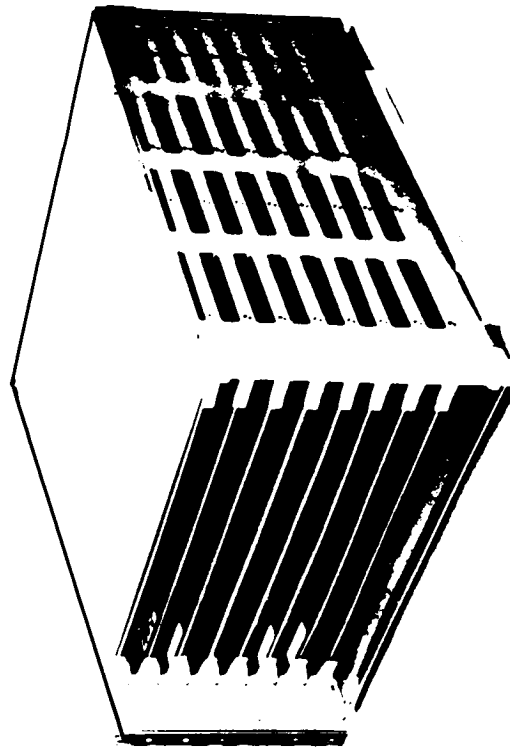
TECHNICAL CONTACT: Thomas J. Bicknell, JPL, (818) 354-2523

ADVANCED DIGITAL SAR PROCESSOR

SYSTEM DIAGRAM



FFT MODULE



- MULTI-MISSION SAR PROCESSOR
- 6000 MEGAFLOP COMPUTE RATE
(FASTER THAN 10 CRAY COMPUTERS)
- 150 MEGABYTES OF HIGH-SPEED MEMORY

- ONE OF FOUR IN SYSTEM
- 1400 MEGAFLOP COMPUTE RATE
- EIGHT OTHER MODULES REQUIRED
TO COMPLETE SYSTEM

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FIBER OPTIC COMPONENT DEVELOPMENT FOR WAVELENGTH DIVISION MULTIPLEXING

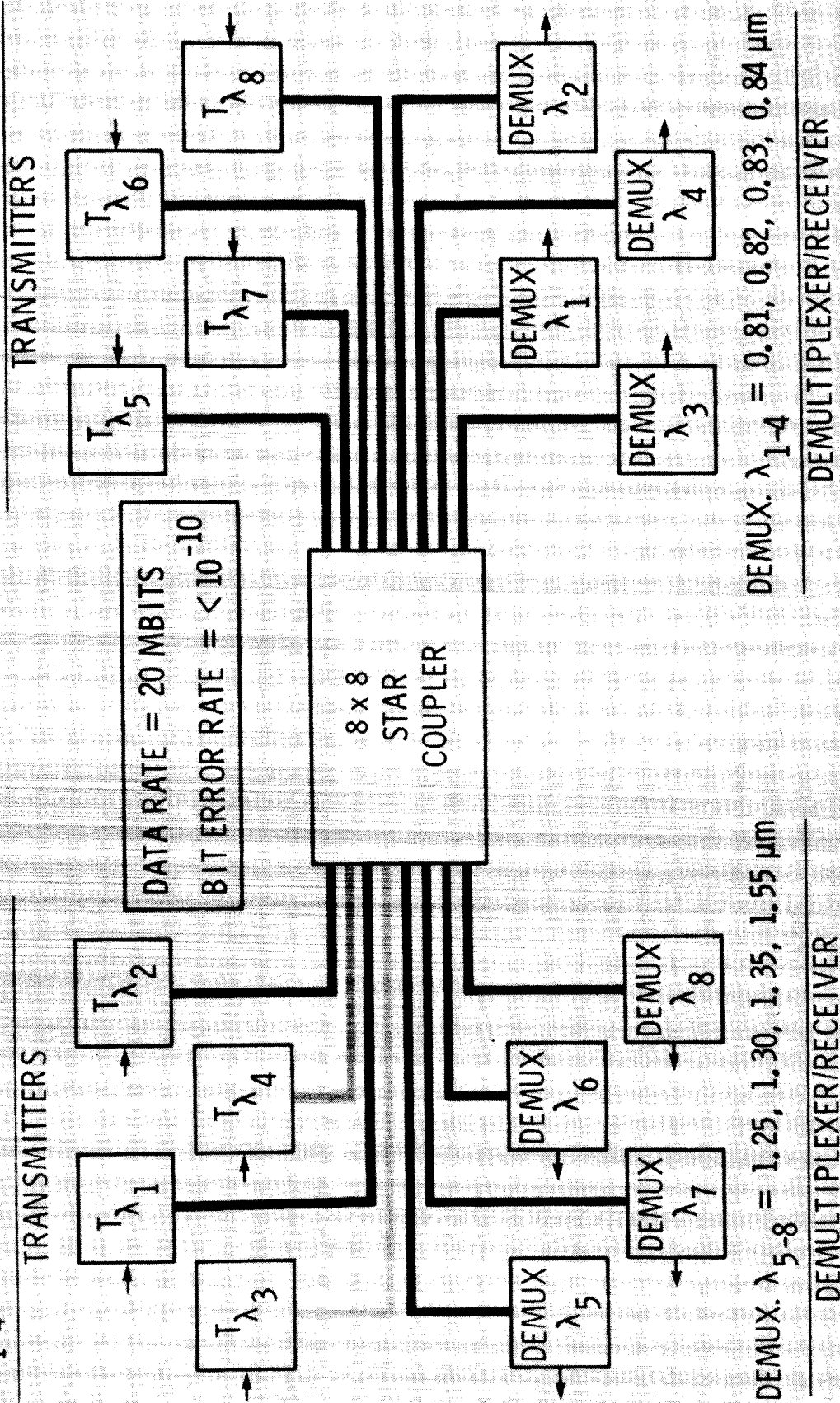
The objective of this work is to develop and demonstrate optical bus components (of the type illustrated in the accompanying figure) for application to Wavelength Division Multiplexing (WDM) information network architectures in Space Station data systems. The WDM approach offers an evolutionary, expandable, fault-tolerant and self-repairing concept through the utilization of a multiplicity of wavelengths in fiber optics. Developments in the past year have centered on the demonstration of wavelength demultiplexers and the evaluation of lasers for use in simulated data systems such as the star bus (shown in the accompanying figure).

A Selfoc optical power divider demultiplexer was demonstrated in the star bus configuration with 10 nanometer wavelength spacing between four laser transmitters (T_1 - T_4) operating at 810, 820, 830, and 840 (Lambda_1 - Lambda_4) nanometers. Operating all four laser transmitters at the above wavelengths simultaneously at a data rate of 20 megabits resulted in a bit error rate of less than 10^{-9} for each transmitter-receiver-demultiplexer combination in the star bus system. An 8-channel Zig-Zag demultiplexer was fabricated; initial tests indicate it is capable of operating at 10 nanometer spacing from 790-880 nanometers at the above data and bit error rates. Stability tests, including life test data, indicated that constricted double heterojunction AlGaAs lasers should provide wavelength stability less than 40 nanometers over 10^5 hour lifetime. A miniaturized version has been designed and is currently being fabricated.

TECHNICAL CONTACT: H. D. Hendricks, LaRC, (804) 865-3535

EIGHT CHANNEL WAVELENGTH DIVISION MULTIPLEXING STAR BUS

$T_{\lambda 1-4} = 0.81, 0.82, 0.83, 0.84 \mu\text{m}$
 $T_{\lambda 5-8} = 1.25, 1.30, 1.35, 1.55 \mu\text{m}$



DIGITAL VIDEO INFORMATION SYSTEM

Video service will be required in the space station information systems: to extend vision, to communicate data, to provide recreation/entertainment/leisure for the crew and customers, to record and store scenes and data, for private communications, for inspection purposes, for training simulation visual displays, graphics displays, computer terminal and other workstation displays, and for caution and warning displays. There has been an explosion of technologies and methods applicable to digital video in recent years. It will be possible in the future to employ digital video from the source (digital video cameras) to the display (digital video monitors), or in other words, an end-to-end digital video capability.

The objective of this effort is to identify an integrated and compatible set of equipment, procedures, and networking for a digital video system to service space station requirements. The approach is to conduct to comparative evaluation of methods of generation (camera), modulation/demodulation, encoding/decoding, distribution/communications, processing and display of digital color video--both studio quality and high definition color video. An example space station system will thereby be defined and critical elements, methods and procedures of this system will be identified. The identified equipment, methods and procedures will then be experimentally constructed and evaluated for performance and compatibility with the space station system requirements.

TECHNICAL CONTACT: Nick Murray, LaRC, (804) 865-3535

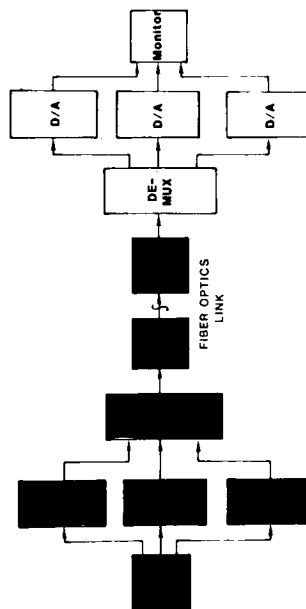
DIGITAL VIDEO

PRESENT TECHNOLOGY LIMITATIONS



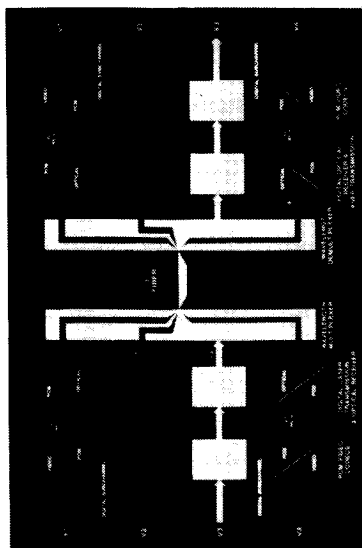
- LOW QUALITY
- LOW RESOLUTION
- LIMITED COLOR

DIGITAL VIDEO SYSTEM TECHNOLOGY



- HIGH RESOLUTION
- COMPATIBLE WITH
DIGITAL DATA SYSTEM

PROGRAM PAYOFF



- SUPPORT OF PRECISION
REMOTE OPERATION ON
SPACE STATION
- ENABLE DIRECT IMAGE
ANALYSIS SUPPORT FOR
TELEOPERATIONS

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SYSTEM ANALYSIS METHODOLOGIES

Two critical user viewpoints in data system development are the design of the user's data management system and the definition of the mission operations concept. Work in these areas is directed at developing and evaluating systematic approaches (i.e., methodologies) for identifying user services and operational performance requirements and relating those requirements to the data system functions. A baseline data system model has been developed by functionally decomposing generic command/control and data handling functions for typical NASA missions. The model defines functional relationships from hierarchical, data flow and interface perspectives using decomposition trees, DeMarco flow diagrams and N^2 charts, respectively.

The methodologies encourage the early definition (and documentation) of user services and mission operations concepts in much more detail than typically experienced today, since this information is required as an input to the data system analysis process. This definition includes identifying mission operations objectives, constraints and scenarios; customizing the generic model to the specific mission; and identifying/characterizing users, services and operations concept-related performance requirements.

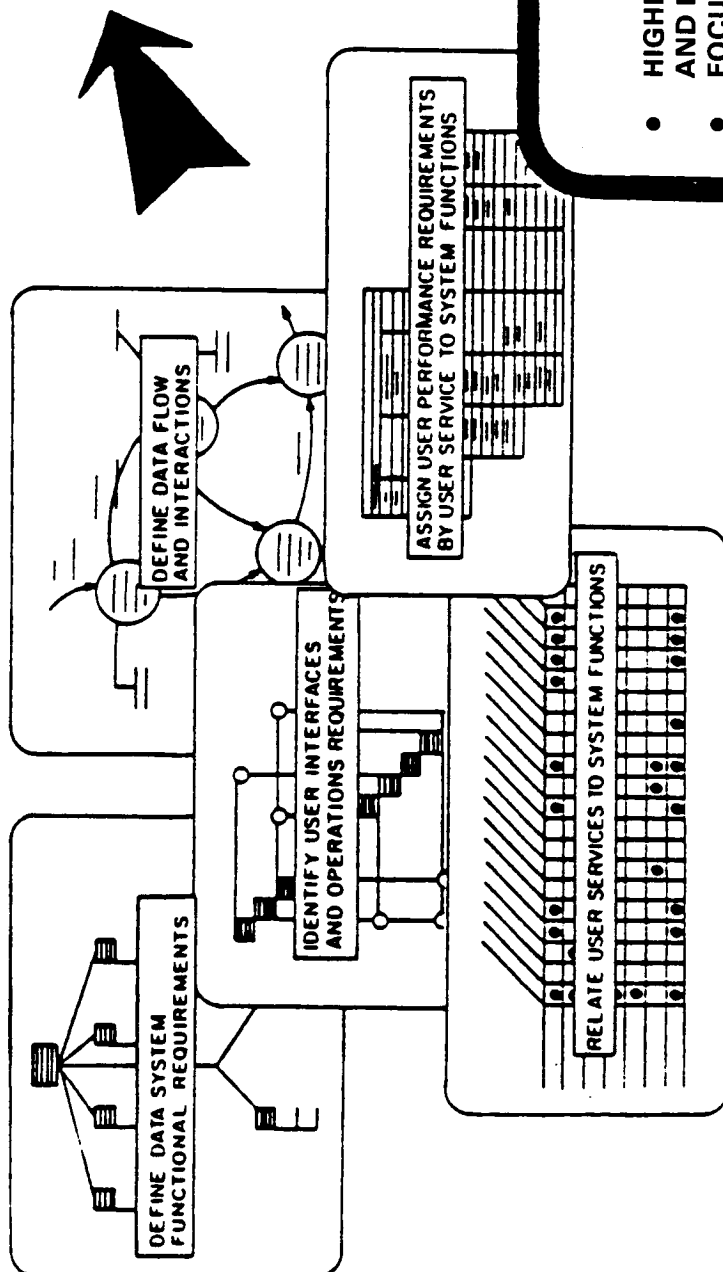
The analysis step iteratively relates user services and performance requirements to data system functions, depending on the nature of the services, and the demand on system resources for each user. As a result, critical performance drivers can be systematically identified and workload assessments for alternative data system concepts defined and compared.

The two methodologies are currently undergoing independent evaluation: data systems analysis techniques applied to the UARS data handling facility, and mission operation concepts being developed for the Attached Shuttle Payloads. These methodologies are expected to be extremely useful tools in the planning and design of large scale data systems for EOS and other Space Station program elements.

TECHNICAL CONTACT: Karen Moe, GSFC, (301) 344-5292

SYSTEMS ANALYSIS METHODOLOGIES

- SYSTEMATIC APPROACH TO DEFINING AND EVALUATING ALTERNATIVE STRATEGIES FOR DATA MANAGEMENT SYSTEMS
- INTEGRATES SYSTEMS ENGINEERING TOOLS
 - DEMARCO DIAGRAMS
 - FUNCTIONAL DECOMPOSITION TREES
 - N² CHARTS



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BENEFITS

- HIGHLIGHTS KEY DATA SYSTEM DESIGN AND PERFORMANCE OPTIONS
- FOCUSES ON EARLY DEFINITION OF USER SERVICES
- MISSION OPERATIONS CONCEPTS

DATA BASE MANAGEMENT SYSTEM AND MASS MEMORY ASSEMBLY

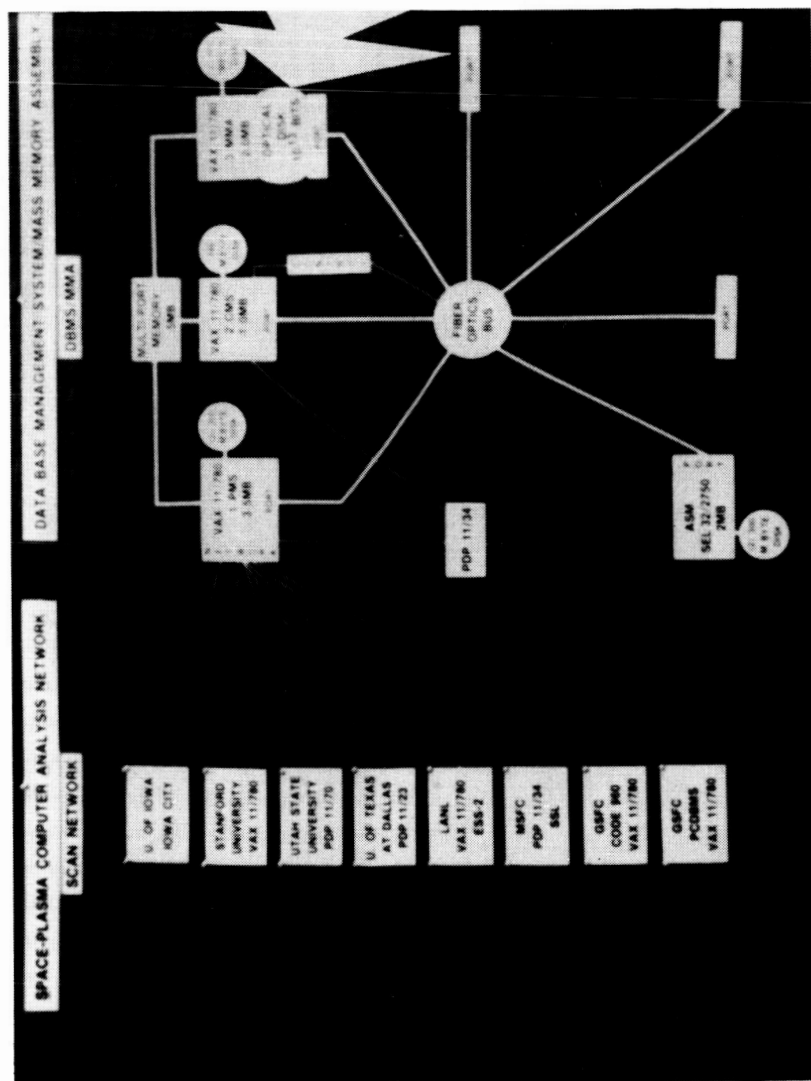
The data base management system (DBMS) and mass memory assembly (MMA) technology development activity addresses two major limitations that exist in present DBMS and MMA systems, (1) the inability to catalogue incoming sensor data at very high rates and make the data available to the user in near real time, and (2) the limited online storage and limited "snap shot" capabilities of present archival systems.

A key DBMS configuration is a fiber optic data bus that utilizes infrared injection laser diodes to transmit data at an internal rate of 100 Mbits/sec and a port to port rate of 50 Mbits/sec. Each port on the bus has a standard interface design that can service communication processors, high rate users or multiple low rate users. Each port has multiple buffers to simultaneously transmit/receive and all ports can simultaneously receive data blocks from a single source.

The mass memory assembly that is interfaces to a port on the fiber optic bus utilizes a laser for reading and recording at 50 Mbits/sec. The recording media is a trilayer 12 inch optical disk with a 10¹¹ bit capacity per disk and online disk storage of 10¹³ bits. Any recorded data can be accessed within 6 seconds by a user. A catalogue of the packets is generated at the same time the packets are being recoded on the mass memory assembly. Packetization and the configuration design makes the sensor and mission data source transparent to the system.

TECHNICAL CONTACT: D. T. Thomas, MSFC, (205) 453-0677

DATA BASE MANAGEMENT AND MASS MEMORY ASSEMBLY



SCAN USER NETWORK AND SYSTEM CONFIGURATION



10 TERABIT
STORAGE UNIT
DELIVERED IN
1984

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FLIGHT DATA SYSTEMS

The application of high-speed data processing and distribution technology to enable on-board high-data rate image and special purpose processing is being investigated in the Data Systems Information Technology research area. A 100 megabit per second, flight qualifiable fiber optic local area network is being developed in brassboard form and will be demonstrated in early FY 85. Fiber optics is the only communications media that does not require impedance matching and has no crosstalk or electromagnetic interference. The fiber optic components have already undergone flight qualification and the critical design review has been completed for the brassboard demonstration. The brassboard will contain a 32 x 32 fiber optic star coupler and dually redundant bus interface units.

The state-of-the-art in on-board processor technology for data handling, compression and information extraction is being advanced through the use of gallium arsenide integrated circuit technology. An adaptable programmable processor chip set architecture has been designed which will operate with a 200 MHz clock. The architecture uses 8-bit slice general processors and gate arrays for I/O and interrupt control. The 8-bit slices will be microprogrammed to emulate the 16-bit 1750A instruction set, with an expected add time of 5 nanoseconds. The chip set can also be configured for special purpose processing functions such as image compression.

TECHNICAL CONTACT: Robert Nelson, GSFC, (301) 344-7809
Warner Miller, GSFC, (301) 344-8183

FLIGHT DATA SYSTEMS

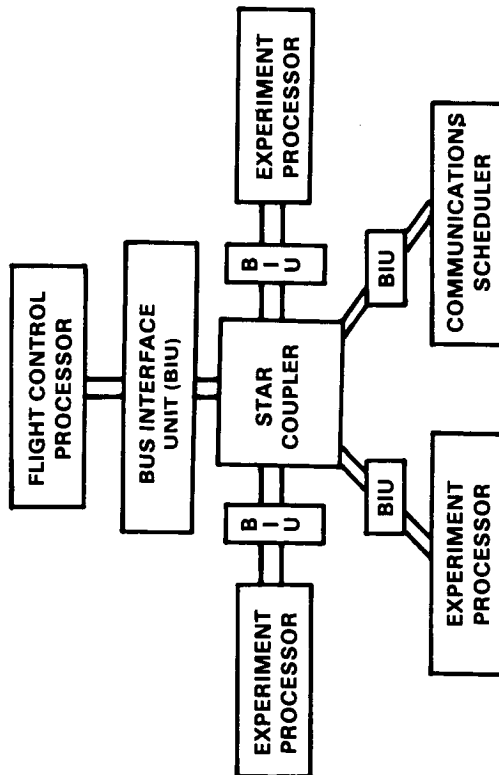
ON-BOARD

FLIGHT

DATA SYSTEMS

- SPACECRAFT
- PLATFORMS
- SPACE STATION MODULES

SPACE STATION MODULES



100 MBIT FIBER OPTIC DATA BUS:

- COMPONENT TESTING AND SPACE QUALIFICATION:
 - 32 X 32 STAR COUPLER
 - FIBER AND OPTICAL EMITTERS AND DETECTORS
- BUS INTERFACE UNIT
- BASE TECHNOLOGY FOR POTENTIAL SPACE STATION APPLICATION

HIGH SPEED ADAPTABLE PROCESSOR

- GALLIUM-ARSENIDE CHIPS PROVIDE HIGH SPEED
 - 5 NANOSECOND ADD TIME
- BIT SLICE AND GATE ARRAY ARCHITECTURE PROVIDE ADAPTABILITY
 - EMULATE GENERAL PURPOSE INSTRUCTION SET (1750A)
 - PERFORM SPECIAL PURPOSE PROCESSING (IMAGE COMPRESSION)

MASSIVELY PARALLEL PROCESSOR (MPP)

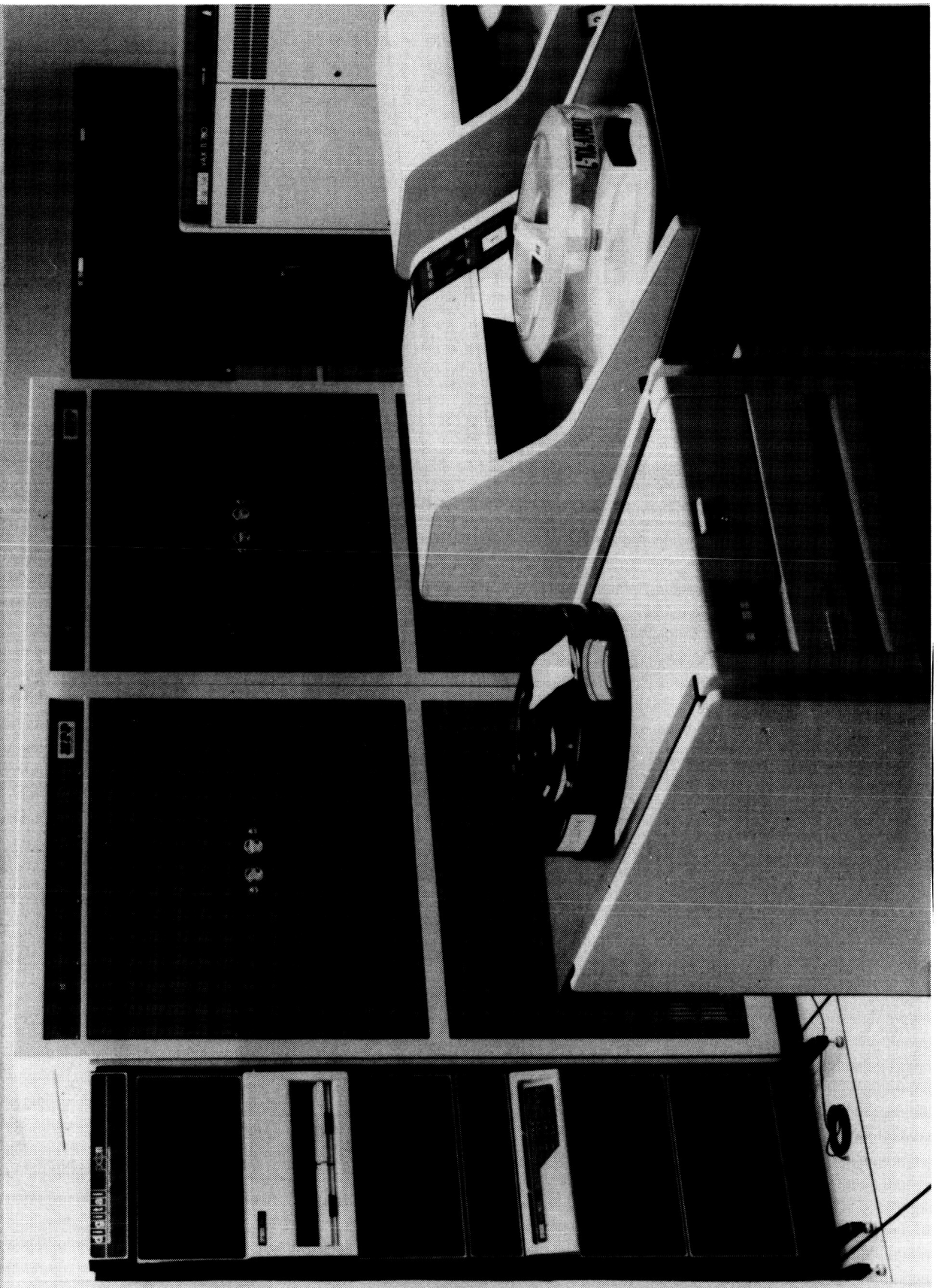
The MPP is an array of 16,384 (128 x 128) processing elements, providing exceptionally high performance for image and large matrix operations. With the high degree of parallelism, the bit-serial processing elements execute 8-bit integer additions at a rate of 6.5 billion operations per second and perform 180 million 32-bit floating point additions and multiplications per second. A staging memory serves as a buffer and interface between the VAX 11/780 that controls the MPP and provides programmable data paths to translate between external parallel data formats and the bit planes of the array memory. The staging memory is currently being expanded from 2 megabytes to 16 megabytes, which will also increase its transfer speed to and from the array memory from 20 to 40 megabytes per second.

A parallel Pascal compiler was completed in FY 84, providing a high level programming language for structuring and coordinating computation on the MPP and sequential operations on the VAX. An initial library of parallel algorithms for image and matrix operations has also been developed. This has greatly extended the programmability of the machine's unique architecture and allowed its application to a diverse set of problems. Current applications include automated and interactive multispectral classification, a two layer fluid model, synthetic aperture radar data analysis and associative data base searches.

TECHNICAL CONTACT: James Fischer, GSFC (301) 344-9416

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MASSIVELY PARALLEL PROCESSOR



ADVANCED GENERAL PURPOSE COMPUTER

In order to help meet the growing general purpose computing requirements of future space systems, work is underway to define a new computer with advanced architecture and device technology features suited to the particular needs of these systems. A typical early application might be the computing systems on the NASA Space Station, although many other potential users would be served as well.

Architectural studies have indicated that a loosely coupled, distributed control, concurrent processing system will best serve general requirements by providing flexibility in throughput, accommodation of a range of device technology speeds, and redundancy where necessary for fault and damage tolerance. The architectural thrust of this research effort has subsequently been focused on the development of a particular computer interconnection scheme and operating system which can exploit a low resolution, data flow approach to software concurrency.

Data flow is the concept of controlling the flow of software execution via the availability of data as opposed to the more common approach of explicitly passing execution control from one program element to the next. The potential for concurrent processing under data flow is more easily expressed than with other forms and may be represented graphically as a directed graph which shows the flow of data between program elements. In a low resolution data flow system, the program elements of concern are complete routines (not simple instructions) programmed in conventional high level languages such as Ada, or HAL/S.

This new approach affords the opportunity to achieve efficient multi-computer utilization at lower hardware and software costs. It also provides a basis for the implementation in operating system software of a highly flexible fault and damage tolerance system with no additional hardware complexity. By performing data flow control via the operating system, concurrent execution and fault/damage tolerance are isolated from both hardware and application software design, thus representing no recurring cost to the system. These architectural features are currently being incorporated into a rapid prototype system for demonstration during the next fiscal year.

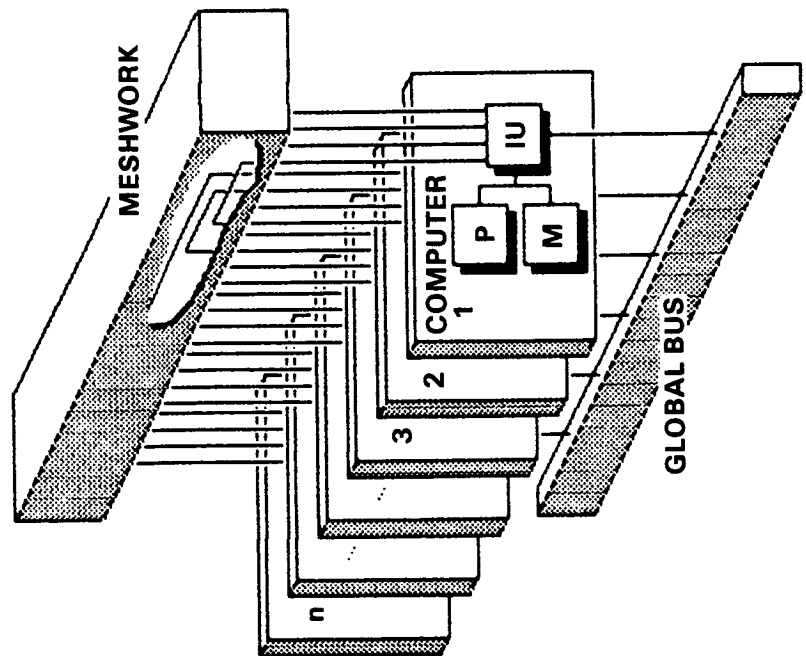
The principal device technology effort of this program is devoted to the insertion of Very High Speed Integrated Circuit (VHSIC) technology from DoD programs into the Advanced General Purpose Computer. The viability of this technology in the time frame of prototype system development is uncertain; however, other technology options have also been reviewed. Issues involved include a combination radiation and single event upset tolerance, performance, availability in adequate quantities, reliability, and other features which are not currently available in any planned systems. Selection of the base technology will be made at the end of the architecture demonstration and in time for initiation of a planned breadboard design effort to culminate in the production of a system for Space Station evaluation.

TECHNICAL CONTACT: David Smith, JPL, (818) 354-4480
Harry Benz, LaRC, (804) 865-3535

ADVANCED GENERAL PURPOSE COMPUTER

SYSTEM ARCHITECTURE

- LOOSELY COUPLED MULTI-COMPUTER
- DATA FLOW CONCURRENT
- SOFTWARE IMPLEMENTED FAULT TOLERANCE
- POINT-TO-POINT INTERCONNECTION MESHWORK
- SPECIALLY DESIGNED GLOBAL BUS FOR DISTRIBUTION PROCESS SYNCHRONIZATION



PAYOFF

- MUCH HIGHER PERFORMANCE THAN EXISTING SYSTEMS
- FAULT AND DAMAGE TOLERANT WITHOUT COMPLEX VOTING OR SWITCHING HARDWARE
- ON-LINE REPAIRABILITY FOR UNINTERRUPTED LONG-TERM SERVICE
- EFFICIENTLY ADAPTABLE TO A WIDE RANGE OF APPLICATIONS THROUGH INCREMENTAL EXPANSION

AERONAUTICS HUMAN FACTORS

The objective of the Aeronautics Human Factors Program is to provide the research and technology base for solutions to the human problems impeding the growth and safety of air transportation. The program has three major thrusts: flight management, human reliability enhancement and human engineering methods.

The flight management thrust is aimed at developing an understanding of crew/cockpit/ATC (air traffic control) interaction that can lead to improved operational performance and capability of the National Airspace System (NAS). It includes the development of supervisory control methods and human/computer dialogue design methods that will enable the "electronic crewmember" and "glass cockpit" concepts, and the development of theories of human perception, cognition, action and crew interaction to enable the supervisory control techniques referred to above.

The goal of the human reliability enhancement thrust is to develop methods for improving the overall reliability of the crew/cockpit/ATC system. This includes: the identification of systematic causes of human error in the cockpit and in ATC through the Aviation Safety Reporting System; the identification and evaluation of the effects of fatigue and circadian desynchronization on aircrews; and the development of comprehensive models of crew error and of methods for controlling the propagation of that error through the system.

The human engineering methods thrust is aimed at developing improved human aviation crew systems. This includes the development of: a fundamental understanding of the phenomenon of workload, improved techniques for measuring crew performance, methods for implementing biocybernetics into the cockpit and an improved simulation technology base.

PROGRAM MANAGER: Dr. Melvin Montemerlo
NASA/OAST/RC
Washington, DC 20546
(202) 453-2784

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HEART RATE AS A WORKLOAD METRIC

Measures of crewmember workload are important tools for evaluating alternative workstation designs, procedures, management structures, etc., since they complement performance measures in their ability to ascertain potential problems. Performance measures show system capability to do a task; workload measures are designed to indicate the crewmember's "reserve capacity" to handle additional tasks.

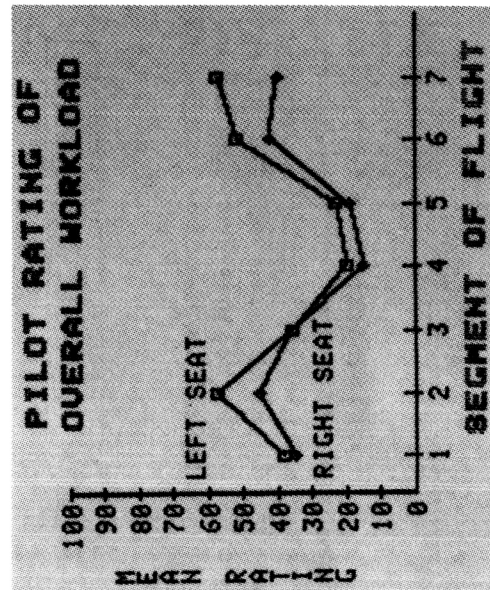
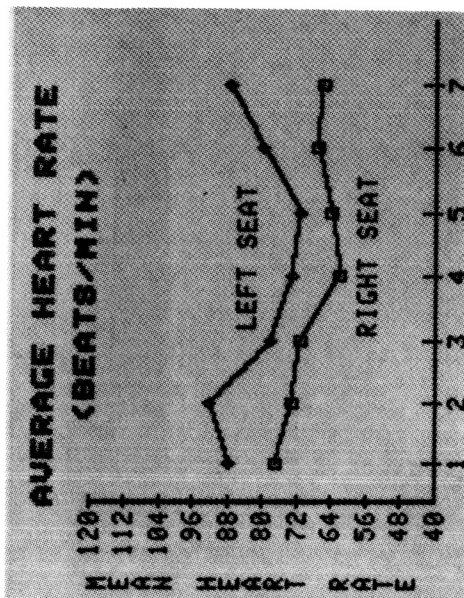
The earliest method of workload measurement, and the one which is still most widely used, is timeline analysis. Unfortunately, while timeline analysis can validly get at overt physical busyness, it is inadequate for mental workload. NASA has, therefore, initiated a research program to improve existing technology for measuring workload.

Most of the workload metrics are developed in the laboratory. Field studies are used for validation. During the past year, a field study was performed in NASA's Kuiper Airborne (C-141) Observatory to test the capability of subjective ratings and of heart-rate to measure the workload of the pilot-in-command (left seat) and the co-pilot (right seat) during performance of their operational tasks. The pilot's task encompasses more stress than overt physical business, while the co-pilot's task was just the opposite.

As shown on the opposite viewgraph, there was good correlation between subjective ratings and heart rate. Also, heart rate was shown to be a more sensitive predictor of the difference between pilot and co-pilot workload than subjective rating. The implication is that heart rate reflects stress rather than busyness. Heart rate is, therefore, a very useful measure in operational situations because it is non-intrusive.

TECHNICAL CONTACT: Sandra Hart, ARC, (415) 694-6072

HEARTRATE AS A WORKLOAD METRIC



HEARTRATE:

- REFLECTS STRESS, NOT BUSYNESS
- IS MORE SENSITIVE TO STRESS THAN SUBJECTIVE RATINGS

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ERROR-TOLERANT CREWSTATIONS: AUTOMATIC DETECTION OF PROCEDURAL ERRORS

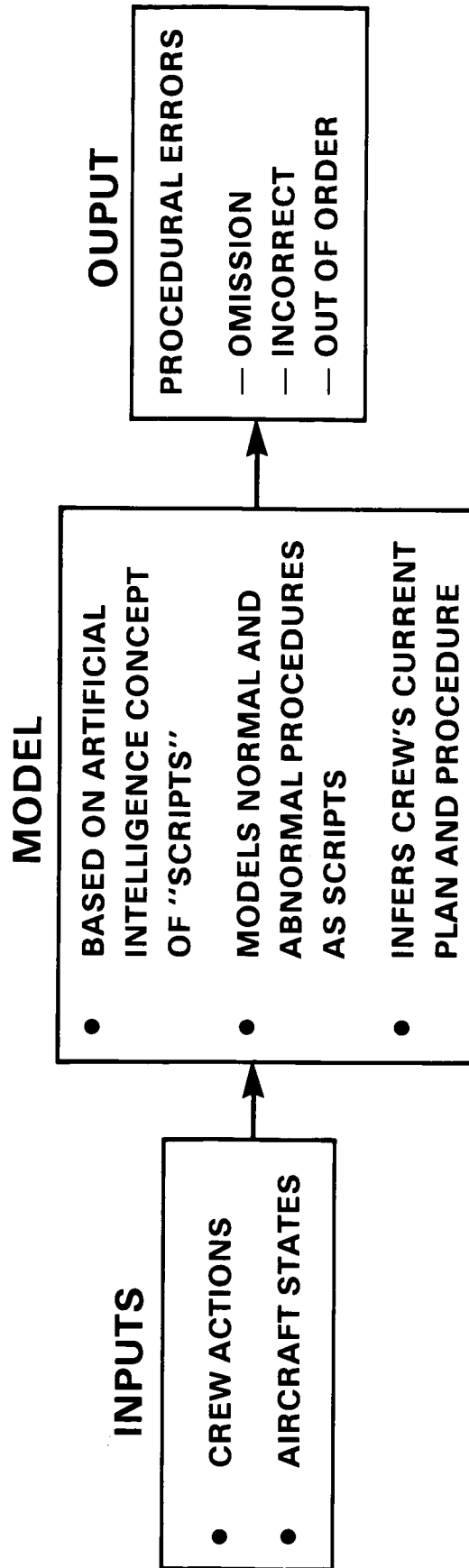
Crew errors during full mission simulations are currently found by humans who painstakingly examine simulator data. It would be preferable to detect these errors seconds after they occurred. A computer program was developed to monitor crew actions through changes in the aircraft controls and state. These actions are compared to a procedure script, which can be considered as a prescriptive model of the procedural aspects of flight. An error is defined as a discrepancy between the crews actions and the script. The program is capable of detecting omitted, incorrect or out-of-order actions as well as certain irrelevant actions.

The computer program was evaluated by using it to analyze data from a full mission simulation in which errors had been identified by human observation. The program was able to detect practically all of the errors identified, as well as some that had been missed by the human judges.

Future plans are to apply the program to data from a more complex, full mission simulation being done at Ames for a 727 aircraft. The program will also be modified and tested as a real time aid to flight crews.

TECHNICAL CONTACT: Everett Palmer, ARC, (415) 694-6073

ERROR-TOLERANT CREWSTATION: AUTOMATIC DETECTION OF PROCEDURAL ERRORS



PSYCHOPHYSIOLOGICAL MEASUREMENTS OF MENTAL WORKLOAD

The evolution of aerospace crew roles from aircraft attitude management to overall system management is accompanied by a corresponding change in the nature of the crew workload from primarily physical activity to primarily mental exertion. Existing methods of workload assessment are based on measures of overt behavior or verbal report and are insufficiently sensitive to mental workload. The objective of this program is to develop mental workload assessment techniques based on physiological measures. These advanced techniques are intended to provide the tools necessary for human factors evaluations of crew station technology advances.

One technical approach employed in this work utilizes the electrical activity of the brain, as recorded from skin-surface electrodes, to examine for features that reflect degree of mental loading. The transient cortical evoked response method and the steady-state evoked response method--two techniques for extracting information from the spontaneous brain response--have previously been shown to exhibit features that reflect mental loading. The steady-state evoked response paradigm lends itself to analysis by techniques that have proven useful in the analysis of engineering systems, e.g., describing function analysis.

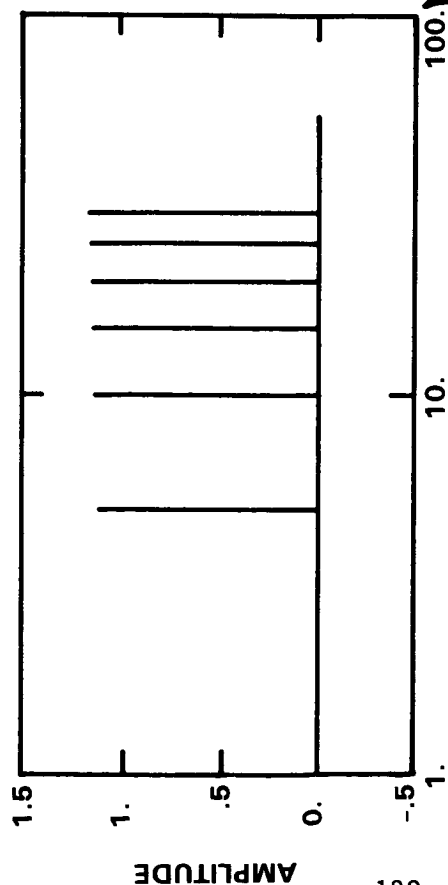
The capability of steady-state visual evoked response experimentation has been implemented at LaRC. The system operates as follows: the intensity of a stimulus light is modulated by a computer-generated signal consisting of a sum of sinusoids; the resulting steady-state evoked brain responses are sampled and frequency analyzed. Currently, the end products of this process are magnitude-ratio and phase-shift plots of the eye-brain system. These data, collected as a range of mental workload levels, are imposed on experimental subjects. The resulting input/output plots are then examined for features that reliably reflect the imposed workload levels.

Future work will involve an analytical study to develop a functional input/output model of the steady state evoked response. These responses will, in turn, be used to identify features of the model that are systematically sensitive to specifiable mental workload changes. The features thus elicited will provide the basis for making inferences about workload changes from brainwave measurements made in operational environments.

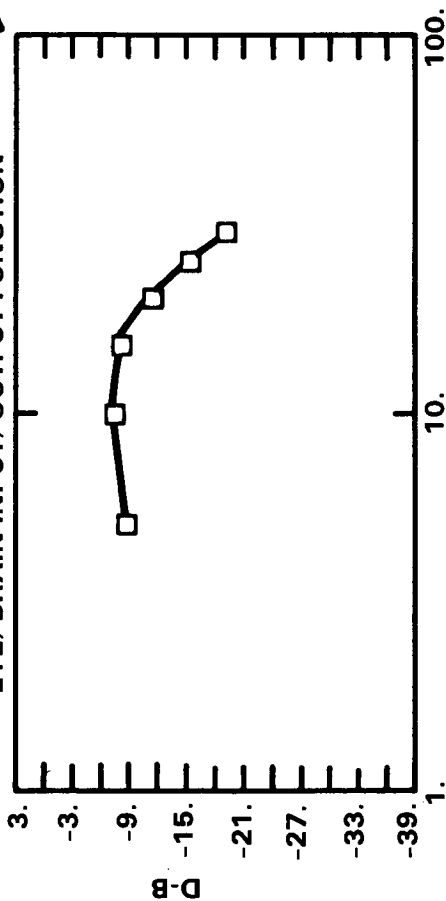
TECHNICAL CONTACT: Alan T. Pope, ARC, (804) 865-3917

PSYCHOPHYSIOLOGICAL MEASUREMENT OF MENTAL WORKLOAD

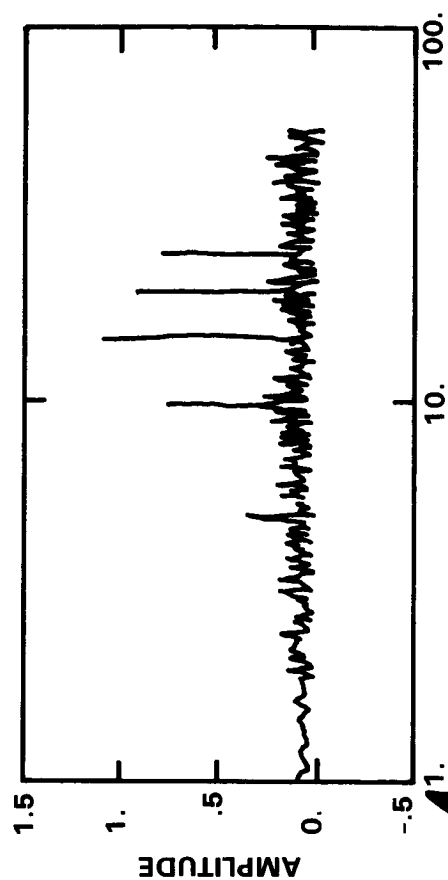
STEADY STATE EVOKED RESPONSE



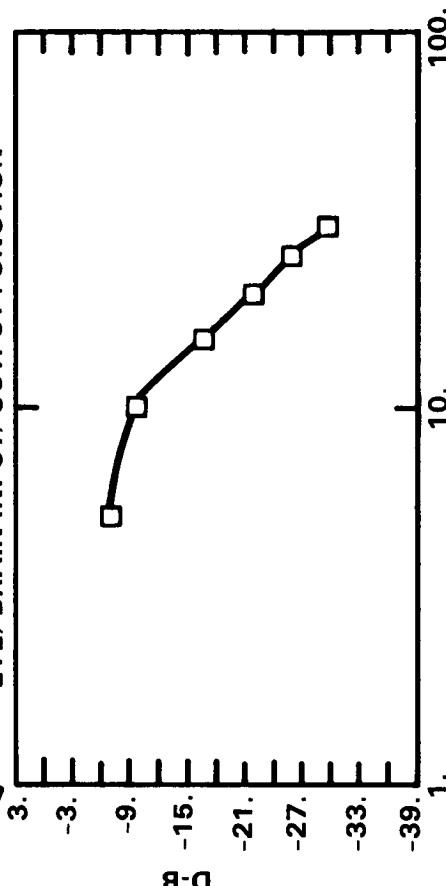
MODULATED LIGHT SPECTRUM
EYE/BRAIN INPUT/OUTPUT FUNCTION



FREQ. HERTZ
LESS WORKLOAD



RESULTING EEG SPECTRUM
EYE/BRAIN INPUT/OUTPUT FUNCTION



FREQ. HERTZ
MORE WORKLOAD

WAKE VORTEX AVOIDANCE THROUGH MULTIPLE-GLIDE-PATH CONCEPT

Wake vortex considerations dictate in-trail separation requirements and, thus, runway throughput capacity. Currently, separation standards for aircraft following the same glide slope are based on allowing time for the strength of the vortex from the preceding aircraft to decay.

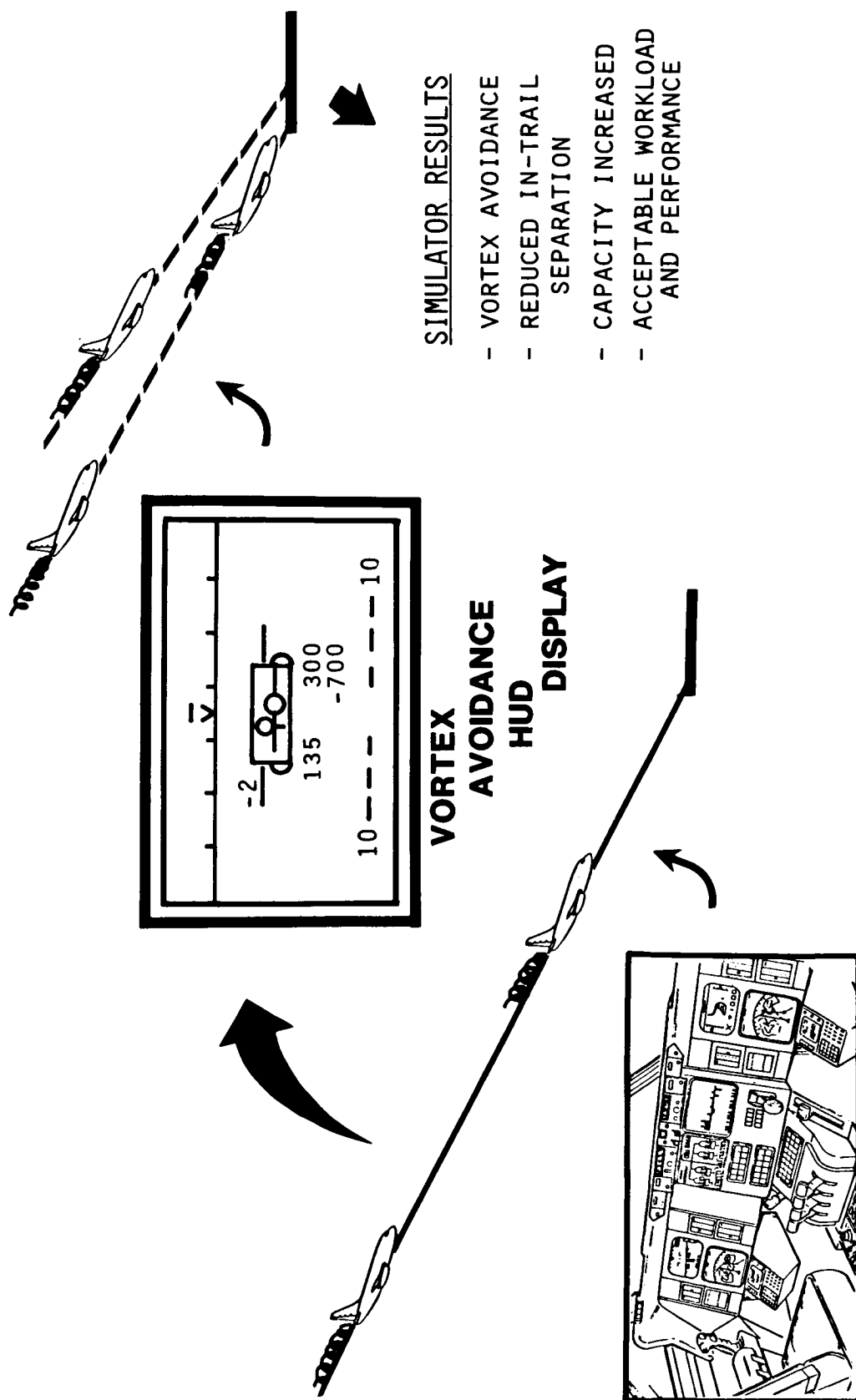
A different approach to the problem, based on vortex avoidance rather than on decay, would place aircraft on different glide paths to a given runway. Earlier considerations of such a concept were abandoned because of several practical problems related to the potential for transgressions by the lead aircraft that could not be detected by the following aircraft. For example, a go-around by the lead aircraft could shed its vortex along the path of the following aircraft.

A vortex avoidance head-up-display (HUD) concept was studied that combined conventional HUD symbology with symbology related to the lead aircraft in a manner such that the pilot could both self-space on the lead aircraft and monitor the lead-aircraft adherence to its designated path. The simulation study assumed the existence of an MLS system to define the separate paths and the existence of a data-link to exchange information among the aircraft. The results indicated that this concept would provide the information required by the flight crew for multiple-glide-path operations.

TECHNICAL CONTACT: Terrence Abbott, LaRC, (804) 865-3621

WAKE VORTEX AVOIDANCE THROUGH MULTIPLE-GLIDE-PATH CONCEPT

PROBLEM: IN-TRAIL SEPARATION DICTATED BY WAKE VORTEX CONSIDERATIONS



FORMAL METHOD FOR HUMAN/COMPUTER INTERFACE DESIGN

Aircraft and spacecraft crews are faced with increasing requirements to interact with on-board computers. Accident and incident data from aviation data bases such as the Aviation Safety Reporting System indicate that problems arising from such interfaces are becoming more common. Formal methods do not presently exist for designing optimal human/computer interfaces. The purpose of this research project is to develop general design tools for analyzing and designing such interfaces.

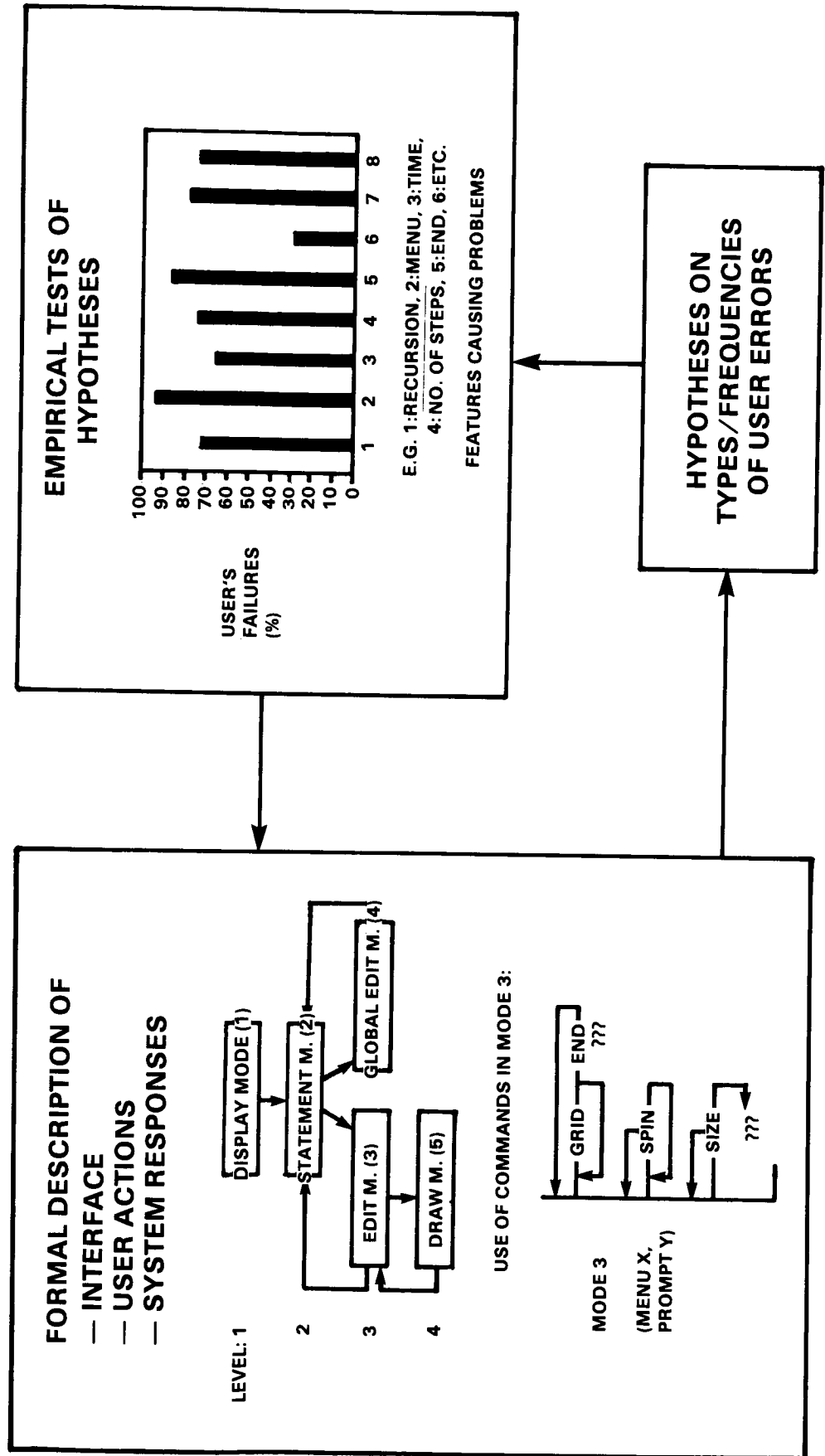
A formal method has been developed for making systematic complete descriptions of user actions and system responses. This allows the analyst to identify flaws and inconsistencies in a system interface and allows the analyst to make hypotheses about the type and number of errors that users will make.

An experiment has been carried out to test the first set of hypotheses resulting from the formal description. Results confirmed most of the predictions about the subject errors and their difficulties in building clear expectancies about system responses. A formal method appears to be a powerful tool for human/computer interface design. Further work is underway to improve the capabilities of the current method.

TECHNICAL CONTACT: Jean-Marc Robert, ARC, (415) 694-6243

FORMAL METHOD FOR HUMAN/COMPUTER INTERFACE DESIGN

DEVELOP FORMAL METHOD



DIRECTION JUDGMENTS USING SPATIAL DISPLAYS: "FIELD OF VIEW" EFFECTS

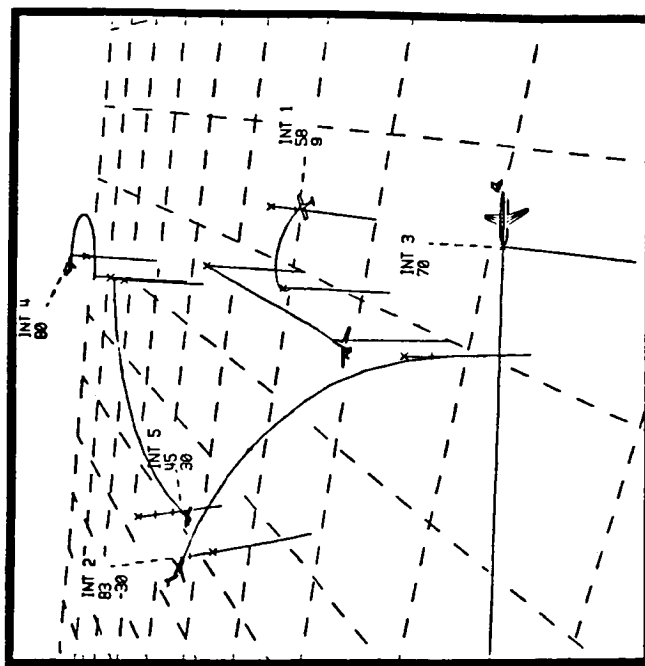
The concept of using "spatial displays," i.e., three-dimensional perspective displays, in aircraft cockpits was developed at ARC in a research program on "cockpit displays of traffic information" (CDTI). It was found that integrating horizontal and vertical information into a single pictorial display could increase response accuracy and speed. It was also found, however, that the parameters used to transform the three dimensional scene onto a two-dimensional screen affected pilot performance. Two important parameters in this transformation are the "field of view" of the display and the eye position of the viewer relative to the objects on the screen. The field of view parameter is analogous to the distortions in photographs introduced by using a zoom lens.

The field of view of the display on the left of the opposite viewgraph is about 60 degrees. An experiment was run in which four different fields of view were used: 30, 60, 90, and 180 degrees. The dependent variable was the pilot's error in judging the azimuth of other aircraft on the display. The best field of view would be the one for which judgment errors are minimal for target aircraft anywhere on the display (-180 to +180 degrees azimuth). It was found that judgment error is sinusoidal as target aircraft azimuth varies from -180 to +180 degrees (upper right corner of the viewgraph) and that the 60 degree field of view turned out to be best, i.e., to have the least area under the curve.

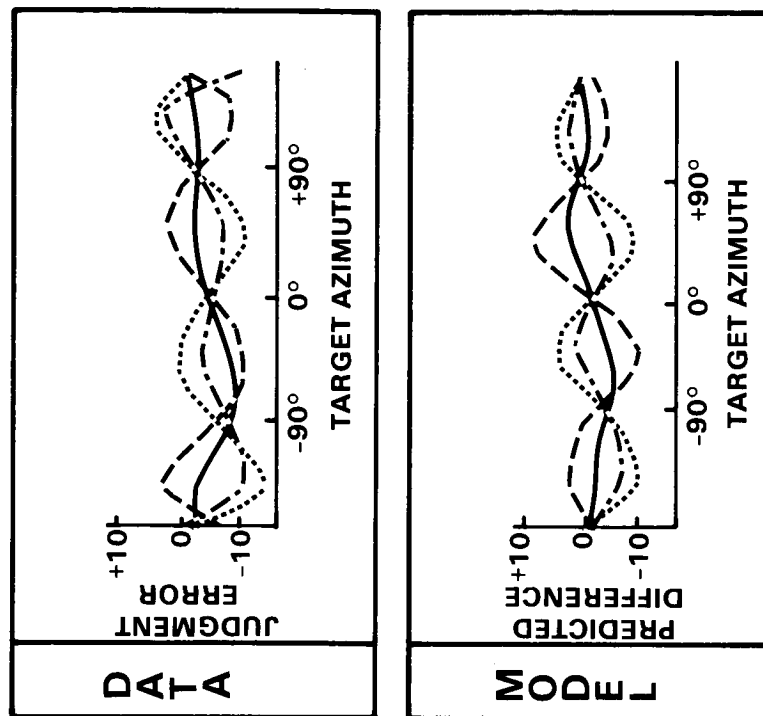
Researchers used the results of the experiment to develop the hypothesis that the two parameters described above were the most important in describing operator performance with spatial displays. They developed a model incorporating those two parameters, the 3-D to 2-D projection and the relation of eye position to objects in the display. The predicted error from this model is presented in the model chart on the viewgraph. The two-parameter model "predictions" are shown to be very close to the data. Another set of data is now being collected to test and validity of the model.

TECHNICAL CONTACT: Michael McGreevy, ARC, (415) 694-6147
Stephen Ellis, ARC, (415) 694-6147

DIRECTION JUDGMENTS USING SPATIAL DISPLAYS: "FIELD OF VIEW" EFFECTS



3-D PERSPECTIVE DISPLAY



FIELDS OF VIEW
30° ---
60° —
90° -.-
120°

WIND SHEAR MODELING

Simulation offers a feasible approach for examining the utility of new technologies and procedures for coping with severe convective weather phenomena such as wind shear. Wind shear models currently employed in simulation studies, however, are very simple analytical forms; validation for these models with respect to either strength or structure does not exist. Based on the premise that the confidence in safety-related studies, which necessarily relies on these models, can be no better than the confidence in the validity of the models themselves, the criticality of this validation deficiency is clear.

As a result of wind shear measurements recently provided from the JAWS Program (Joint Airport Weather Studies), the basic information required to correct this deficiency exists, but special techniques were required to implement the JAWS wind field measurements in simulation. For example, the JAWS data is taken with respect to a grid system that is very coarse when compared with aircraft dimensions. Also, being actual measurements, the data contains noise. A technique using fluid-flow theory to smooth and interpolate the JAWS measurements was developed during this study. This in turn provided a validated model for simulation.

TECHNICAL CONTACT: Roland Bowles, LaRC, (804) 865-3621

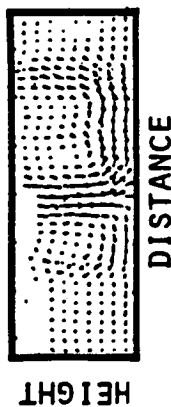
WIND SHEAR MODELING

PROBLEM:

LACK OF HIGH-FIDELITY WIND SHEAR MODEL FOR SAFETY-RELATED STUDIES
OF A/C PERFORMANCE/CREW PROCEDURES/AVIONICS SYSTEM BENEFITS

WIND VELOCITIES (JAWS)

- REAL-WORLD MEASUREMENTS
- BUT, COARSE GRID

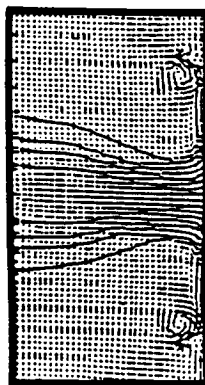


+

THEORY

- FLUID-FLOW-BASED
- SMOOTHING
- INTERPOLATION
- PREDICTION

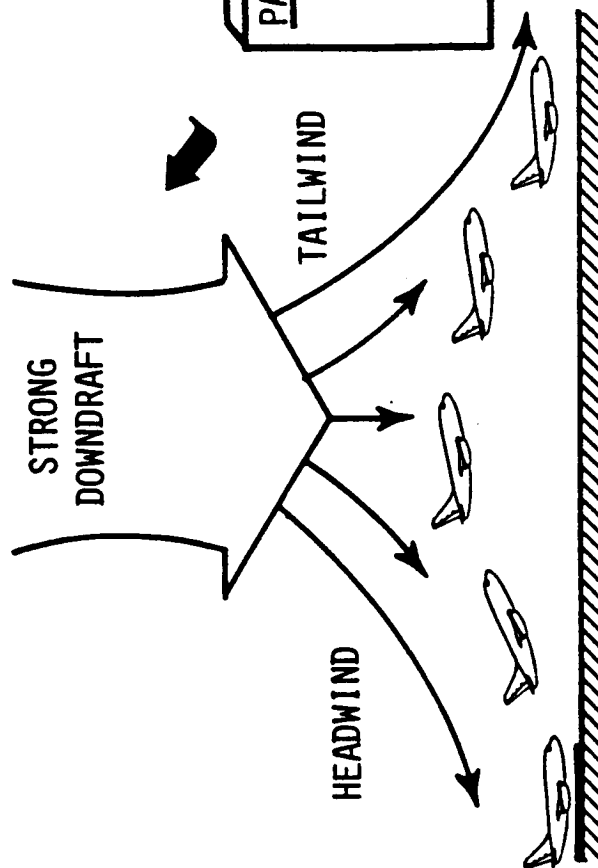
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RESULT:
HIGH RESOLUTION MODELS
BASED ON ACTUAL
WIND SHEAR MEASUREMENTS

PAYOFF:

- REALISTIC REPRESENTATION OF SEVERE WEATHER
- VERIFIED CAPABILITY FOR CONDUCTING SAFETY-RELATED RESEARCH



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WORKLOAD PREDICTION: STANDARDIZED SCENARIO DESIGN

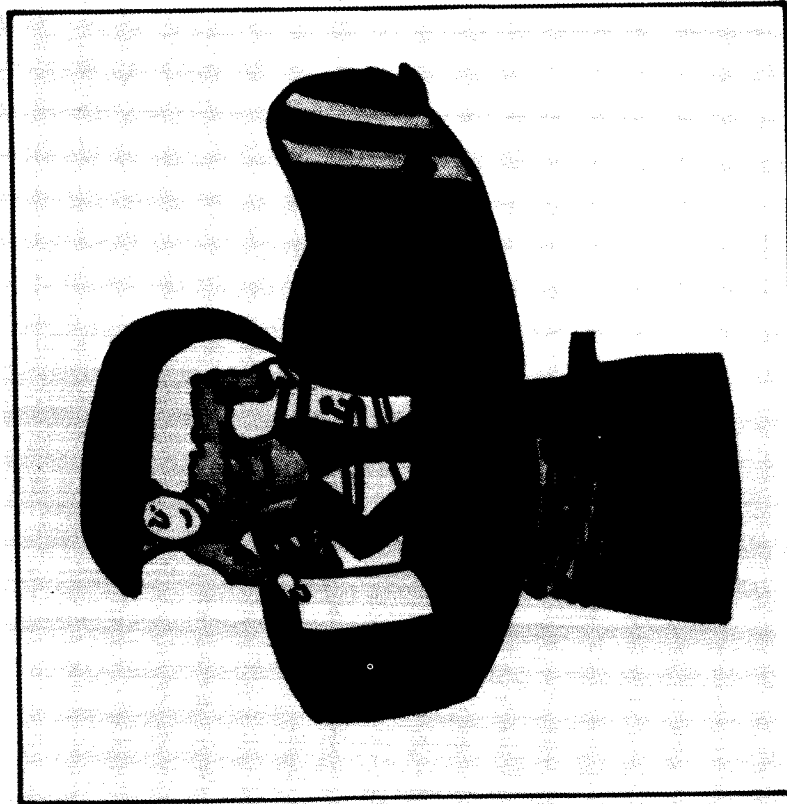
Research and development on workload measurements has been hampered by the lack of standardization of tasks used to validate measured workloads. Many of the contradictory findings that have occurred have resulted from differences in tasks used. A standardized method for the design of scenarios with predictable differences in workload would be even better than a standard fixed set of tasks. This standard would provide researchers with greater flexibility.

A scenario design methodology has been developed at Ames Research Center to meet the requirements of task standardization. It was done by analytically breaking-down typical flying scenarios into elementary tasks. Pilots were asked to perform each elementary task (e.g., fly a given heading while all other parameters are automatically held constant), and then to do pairs of such elementary tasks (e.g., fly a given heading at a given airspeed with all other parameters automatically held constant). Finally, they were asked to fly the entire mission with no parameters held constant. The subject pilots were asked to rate the workloads of each of the single tasks. At the same time, they were given another measure of workload, secondary task performance.

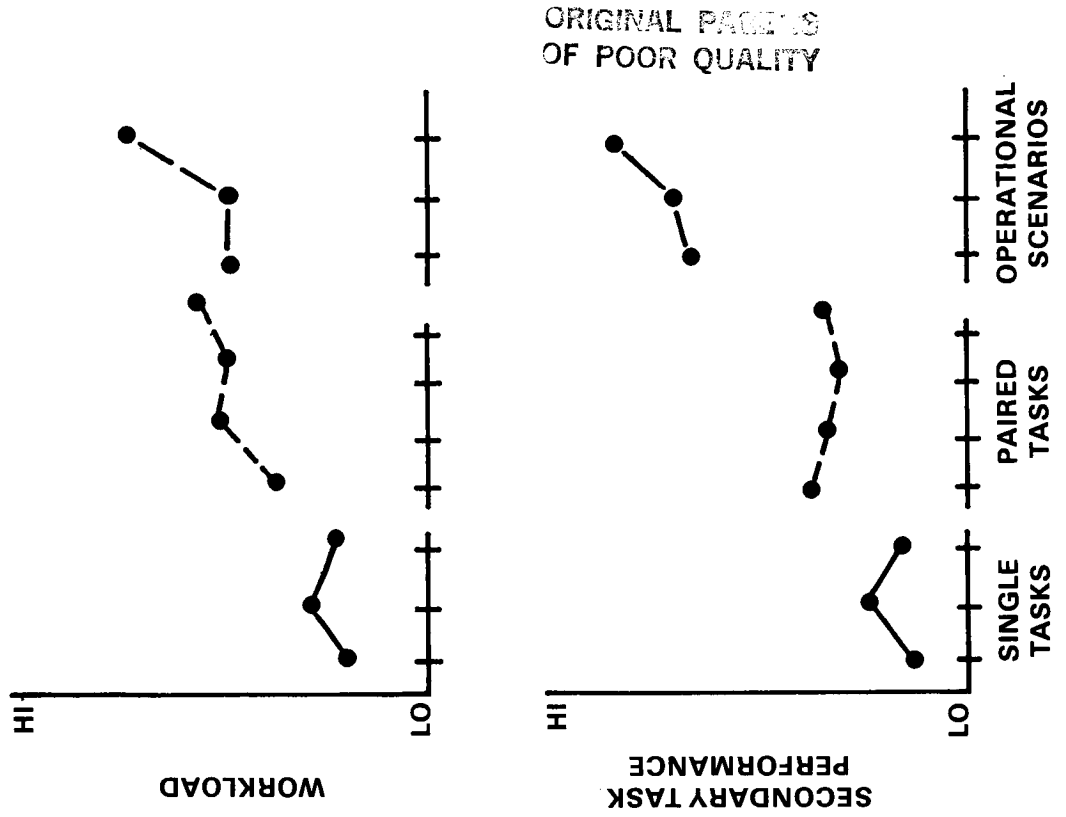
A sample of the findings are presented on the viewgraph. The results show excellent correspondence between the two types of workload measures. In addition, the predicted trend of increasing workload from single tasks to paired tasks to full mission tasks (operational scenarios) is depicted.

TECHNICAL CONTACT: Sandra Hart, ARC, (415) 694-6072

WORKLOAD PREDICTION: STANDARDIZED SCENARIO DESIGN



GENERAL AVIATION
SIMULATION SCENARIOS



SPACE HUMAN FACTORS

The objective of the Space Human Factors Program is to provide a technology base for optimal allocation of functions to humans and to automation, and for designing safe, efficient, effective roles, workstations, tools, and procedures for space operations. The program has four major thrusts: astronaut/crewstation interaction, teleoperation, habitability and extravehicular activity (EVA) performance aids.

Humans will play a significant role in the Space Station both in orbit and in ground control. Guidelines must be developed for the human/systems interface on the Space Station, including teleoperation, and in particular for ground controllers. Since much of their work will be with computers through advanced data display and control hardware, guidelines must be developed which incorporate the latest information on human capabilities, limitations and tendencies in using them. Humans will not only work but live in space, therefore habitability and architecture guidelines must be developed based on the impact of design parameters on human performance and behavior.

PROGRAM MANAGER: Dr. Melvin Montemerlo
NASA/OAST/RC
Washington, DC 20546
(202) 453-2784

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WORKLOAD MEASUREMENT FOR SPACE SUIT DESIGN

Johnson Space Center continually evaluates new design features for space suits. Standard assessment procedures include the use of dynamic reach measurement devices, ergometers and oxygen consumption measures. A joint meeting of JSC and ARC researchers to test and prioritize R&D tasks produced the idea of modifying workload measurement batteries developed by ARC for possible application to the evaluation of alternative space suit design features.

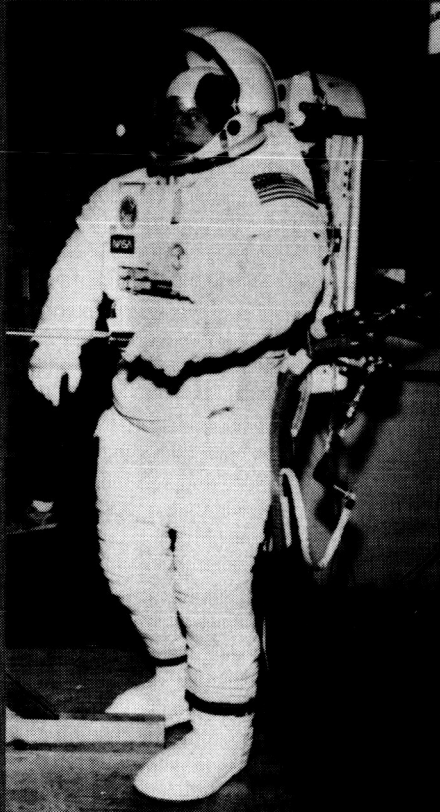
ARC responded by developing a workload/performance measurement battery from test methods previously validated in other research areas. These include performance measures of a psychomotor task and a bipolar subjective rating scale. The test battery has been delivered to JSC and is now in use.

TECHNICAL CONTACT: Sandra Hart, ARC, (415) 694-6072
Barbara Woolford, JSC, (713) 483-4065

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**JOINT
NASA JSC/ARC
EXPERIMENT**



OBJECTIVE:

to compare alternative space suit designs
for upper body comfort and mobility.

APPROACH:

perform laboratory tasks that impose
predictable levels of decision making
and response execution difficulty before
and after upper-body exercises.

EXPERIMENTAL TASKS:

Exercises: torque wrench, rope pull,
weight transfer, and
bicycle ergometer

Decision Task: right/left, memory,
and math

Target Acquisition: control stick detection,
target difficulty

**MEASURES OF PERFORMANCE AND
SUBJECTIVE EXPERIENCE:**

Physiological - heart rate, oxygen uptake

Subjective Opinion - comfort scale,
bi-polar ratings

Performance - reaction time, movement time
% correct, tasks done

ADVANCED EVA SUIT TECHNOLOGY

EVA has been identified as a major element of Space Station operations. Historically, the role of EVA has been one of extreme conservatism, in that EVA was (and is) either planned as a short duration activity or used for contingency operations of minimal duration. The EVA hardware was subsequently designed to meet these requirements, but with the luxury of ample time between missions for refurbishment, resizing, and routine maintenance.

The current baseline (STS) EVA system will not meet the requirements of routine Space Station EVA operations. Due to the extensive number of EVA hours being projected for Space Station, issues that have not been of concern in the past will become drivers in the selection and development of technologies required to meet routine Space Station EVA requirements.

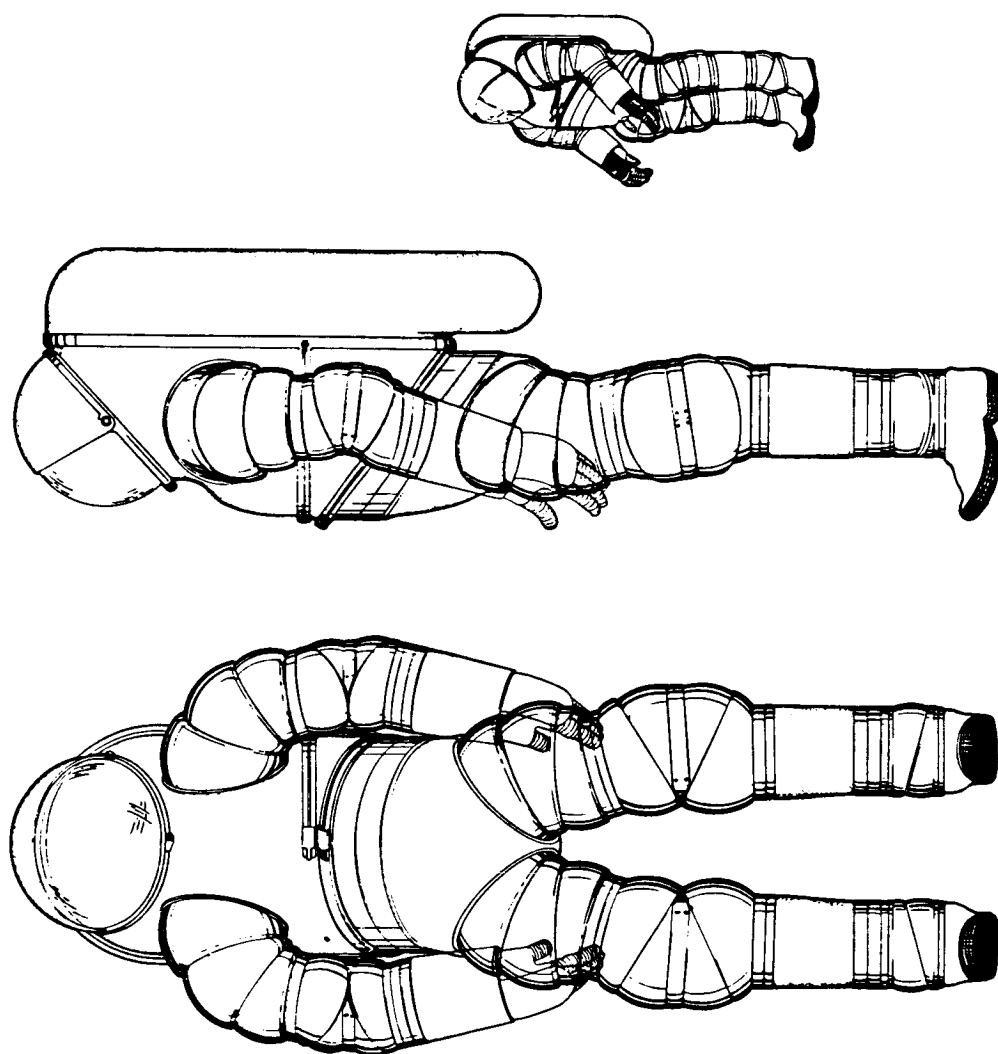
The Ames Research Center has an ongoing development program to address EVA suit technology issues for Space Station. The program emphasis is being placed on technology areas that provide:

- o No prebreathing requirement
- o Improved suit and glove performance
- o Increased hardware and system life
- o Hazard protection (radiation, mechanical)
- o Minimal maintenance
- o Quick change sizing capability
- o Reduced manufacturing and operations costs.

These technologies will be demonstrated, tested and evaluated in a fully functional space suit configuration (AX-5 Hard Space Suit Demonstrator). This suit is being designed to operate at one atmosphere internal pressure. Completion of two suits is projected for August, 1985.

TECHNICAL CONTACT: Hubert C. Vykukal, ARC, (415) 694-5386

AX-5 HARD SPACE SUIT



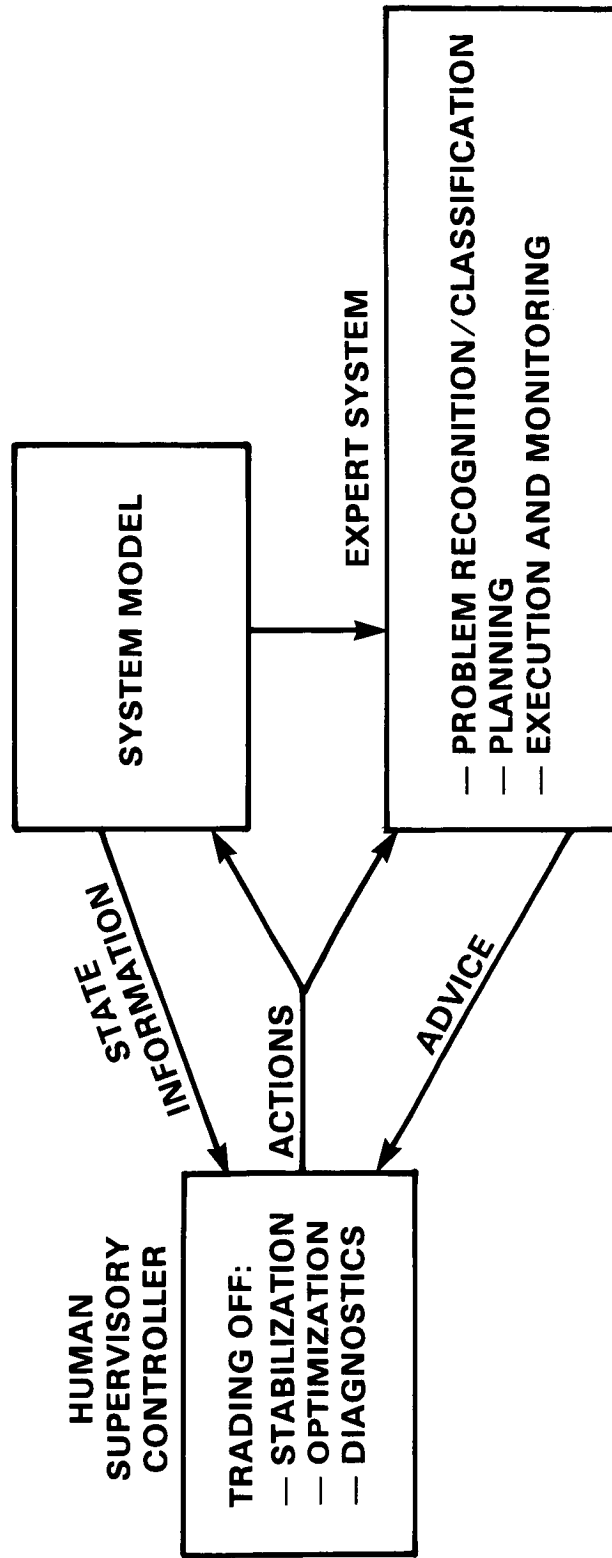
ENHANCING HUMAN SUPERVISORY CONTROL THROUGH EXPERT SYSTEMS

Operation of complex dynamic systems, such as modern aircraft and spacecraft, which incorporate a number of highly automated subsystems is referred to as "supervisory control." This terminology indicates a qualitative change in the role of aircrews and spacecrews from that of attitude controllers to that of systems managers. The operation of complex systems requires that the operator make continuous trade-offs among his goals of stabilization, optimization and system monitoring/diagnosis. The use of expert systems, which has previously been limited to off-line, non real-time passive advisors to experts (e.g., MYCIN and PROSPECTOR), are now being actively considered for on-line, real-time active assistance to aircrews and spacecrews.

The purpose of this research project is to develop guidelines for the use of rule-based models (expert systems) in human supervisory control of aircraft and spacecraft. The approach has been to develop a model of a simplified task (process control) and a rule-based model for supervisory activities such as problem recognition and classification, planning, and execution and monitoring. The rule-based model is used to analyze subjects' actions in real time and provide advice, thus functioning as an on-line expert system. The model provides situation assessment information telling what procedure was currently applicable; it informs subjects if their actions are inconsistent with the current procedure, and gives them performance feedback on plant stability. An initial experiment showed that aided subjects performed somewhat better than unaided subjects. Basic research will continue in this area.

TECHNICAL CONTACT: Everett Palmer, ARC, (415) 694-6073

ENHANCING HUMAN SUPERVISORY CONTROL THROUGH EXPERT SYSTEMS



MODEL-BASED GUIDELINES FOR ELECTRONIC DISPLAY FORMATTING

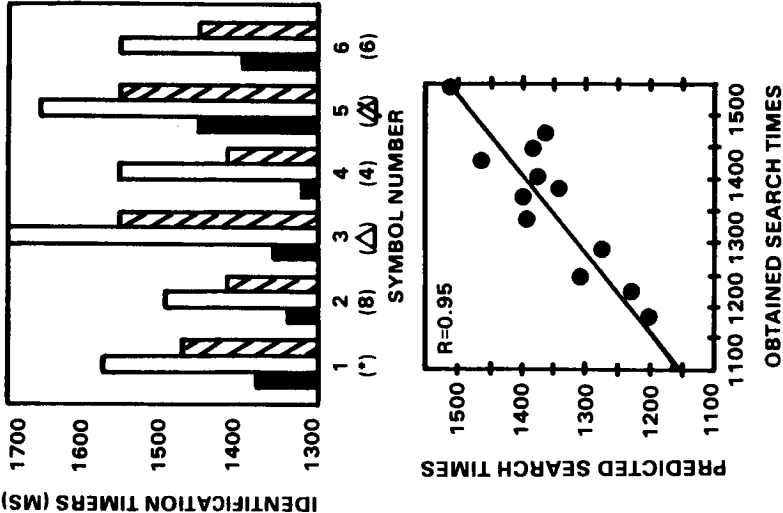
Traditionally, the selection of symbols and the formatting of electronic displays has been relatively unsystematic, and guided more by the wisdom and experience of the designer than by empirically validated guidelines. The purpose of this research project is to explore the possibility of developing a more structured approach to display design and evaluation. The goal of the research is to provide the display designer with a means of simulating the impact of design options on the operator's ability to acquire information from the display. Thus the designer could quickly test alternative sets of symbols and could make optimal selections.

The approach taken was to develop a model of the human operator using a display. The model focused on search time and discrimination time. Although other mental operations are used in extracting information from a display, they are dependent on those two fundamental operations. An important criteria for the model is that the task is described in terms both meaningful and useful to the designer, and that those terms be concrete and under the designer's control.

The first series of experiments defined the display variables that determined search times, and allowed the development of a highly predictive search model (center box of the opposite viewgraph). The data from these experiments provide a base for examining alternative models of visual similarity and symbol confusibility. Current efforts are directed at identifying adequate models of visual discriminability.

TECHNICAL CONTACT: Roger Remington, ARC, (415) 694-6243

MODEL-BASED GUIDELINES FOR ELECTRONIC DISPLAY FORMATTING

HUMAN OPERATOR MODELS	EMPIRICAL TEST	GUIDELINES
<p>INTERFACE DEVELOPMENT SYSTEM (IDS):</p> <p>BASED ON A FORMAL DESCRIPTION OF THE OPERATOR, THE DYNAMIC SYSTEM AND THE INTERFACE, THE IDS WILL PRODUCE A HUMAN FACTORS CRITIQUE, A MONTE CARLO SIMULATION OF THE HUMAN-MACHINE SYSTEM AND A RAPID PROTOTYPE OF THE SYSTEM FOR EMPIRICAL TESTING.</p>	 <p>The figure contains two charts. The top chart is a bar graph showing 'IDENTIFICATION TIMERS (MS)' on the y-axis (1300 to 1700) against 'SYMBOL NUMBER' on the x-axis (1 to 6). For each symbol number, there are three bars: a solid black bar, a hatched bar, and a solid white bar. The bottom chart is a scatter plot with 'OBTAINED SEARCH TIMES' on the x-axis and 'PREDICTED SEARCH TIMES' on the y-axis, both ranging from 1100 to 1500. It shows approximately 15 data points and a regression line with the label 'R=0.95'.</p>	<ul style="list-style-type: none"> • SYMBOL FAMILIARITY • SYMBOL CONFUSIBILITY • DISPLAY DENSITY

SPATIAL FORMATS: NEW FRONTIER FOR ELECTRONIC DISPLAYS

Prior to the introduction of electronic displays into the crewstations of aerospace vehicles, visual displays were primarily of the electromechanical type and thus were limited to two dimensions. Electromechanical attitude displays were, and still are, "eight-ball" configurations which presented up-down and left-right information pictorially; horizontal displays presented ground track information using moving pointers driven by navigational aids.

As electronic displays such as cathode ray tubes were introduced, the tendency was to present electronic versions of the electromechanical displays; vertical information was presented on one display and horizontal information on another. If vertical information was presented on a horizontal display, as was done in experimental displays of traffic information, it was presented as alphanumeric data embedded in a graphic display. The disparity of types of information, graphic and alphanumeric, caused the operator to process the data and thus increased reaction time and led to errors.

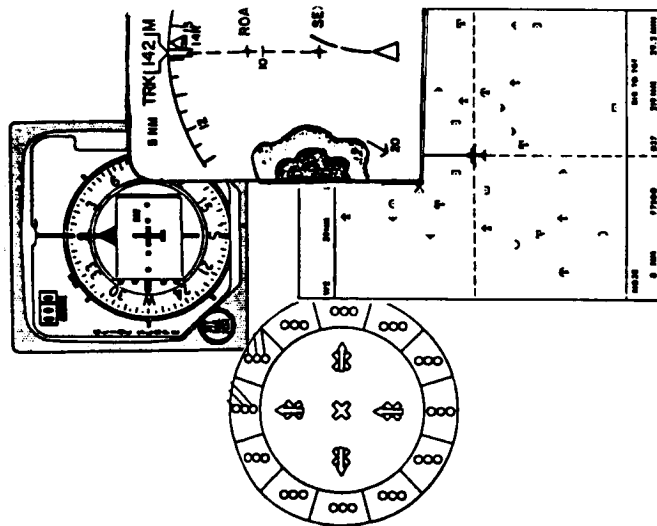
An exciting development in crewstation design has been the introduction of the concept of integrating horizontal and vertical data into a single two-dimensional graphic (pictorial) display. This is done through the use of three-dimensional perspective displays (right half of opposite viewgraph). Such displays have already been shown to decrease reaction time and increase accuracy in operator response.

Initial research has shown that improved performance can be achieved by incorporating deviations from true perspective, such as the use of aircraft icons which are larger than they would be in true perspective. The use of different scales for the horizontal and vertical dimensions can also suffice for this purpose. Guidelines for the formatting of three-dimensional perspective displays must be developed to ensure that operator performance is maximized. This research is now underway at Ames Research Center. Work is also underway to transfer this technology to space, both for use by astronauts in a shuttle or space station, and for ground control.

TECHNICAL CONTACT: Michael McGreevy, ARC, (415) 694-6147
Stephen Ellis, ARC (415) 694-6147

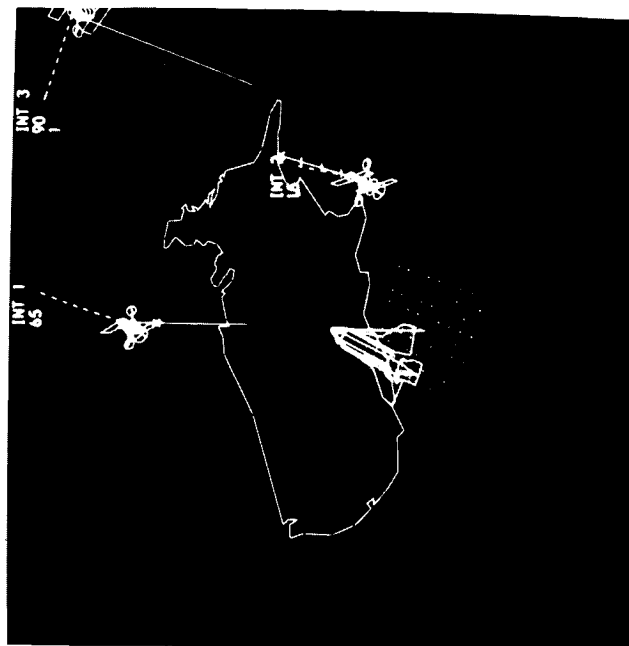
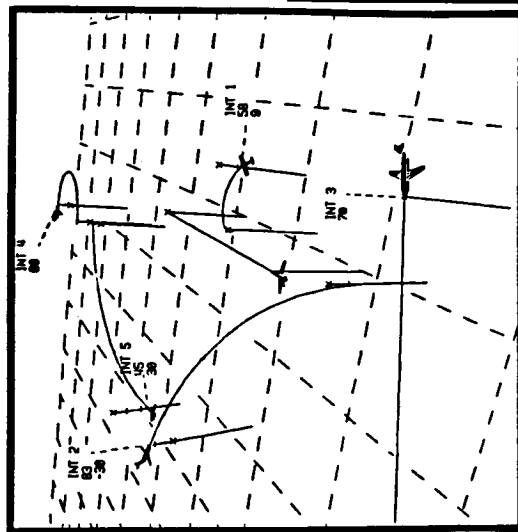
SPATIAL FORMATS: NEW FRONTIER FOR ELECTRONIC DISPLAYS

2-D FORMATS



- TRADITIONAL DISPLAY DESIGN
- SEPARATE HORIZONTAL AND VERTICAL DATA

3-D FORMATS



- REDUCES COGNITIVE LOAD
- DESIGN GUIDELINES REQUIRED

EXTRA VEHICULAR ACTIVITY (EVA) PERFORMANCE AIDS

Development activities in EVA performance aids at JSC have focused around space station servicing tasks. Concepts for a helmet mounted display, a powered glove end effector and a generic work station for EVA crewmen were examined during FY 84.

Helmet Mounted Display - The helmet mounted display is a concept that allows several types of EMU information to be displayed in a convenient manner. Life support instrumentation, computer detected cautions and warning including corrective actions, and tutorial instruction which might include schematics and text information on maintenance and repair items can all be included. Several design concepts have been investigated, and at this time, the CRT appears to be the best choice for video information needed in this concept. Other display technologies such as electroluminescence, plasma, light emitting diodes, and liquid crystal displays will be reevaluated as their technological display capabilities increase.

The most significant result of this project is the indication that a reasonably compact, lower power, virtual image system can be built. Since the feasibility unit has not yet been built, human factors information such as ease of use, distraction from main work task, visibility in high lighting conditions, and display duty cycle as well as overhead reliability still remain as major questions.

Power Assisted Glove End Effector - The purpose of this device is to create a power tool system to facilitate the construction, assembly and servicing tasks of the Space Station during EVA activities. When using a pressure suit, the use of hand tools can be tiring due to excessive hand fatigue. The main thrust of this program is to study the man/tool interface problem and provide at least one solution to minimize hand fatigue.

The present concept is to install "stress strips" in the existing gloves, which minimizes the needed travel distance to control a tool and allows that movement be sensed where glove movement is easiest. Studies also identified a potential need for audio feedback. Future work will explore the installation of audio sensors in the glove and the human factors of feedback in using hand power tools.

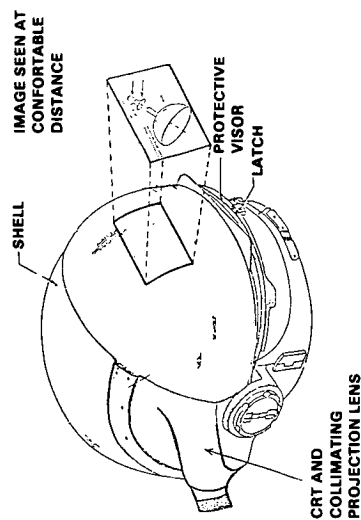
Generic Work Station - The generic work station concept is for a device that an EVA crewman can take to a remote site, which may be either prepared or unprepared, and set up as a positioning and support aid for EVA activities. Major program elements include looking at waist and foot restraints, single or multiple structural attach points, and to trade-off the reach and positioning of the mechanism against the overall rigidity and restraint capability. Results to date have shown that a distributed load single attach point gives better positioning capability and portability, and can give sufficient restraint capability. A four degree of freedom "arm" will be tested in neutral buoyancy facilities to work out final design and human factors requirements during future program activities.

TECHNICAL CONTACT: Manuel Rodriguez, JSC, (713) 483-5536

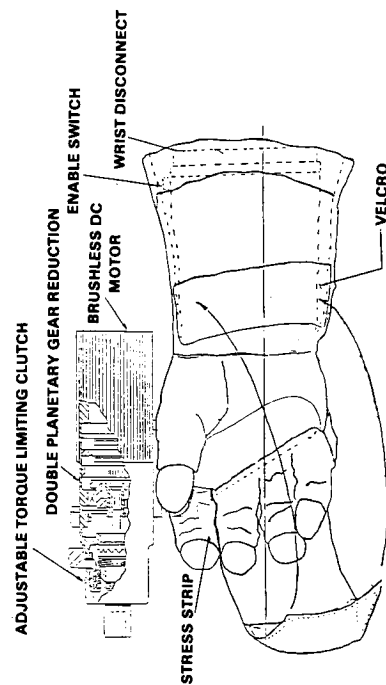
EVA PERFORMANCE AIDS

HELMET MOUNTED DISPLAY

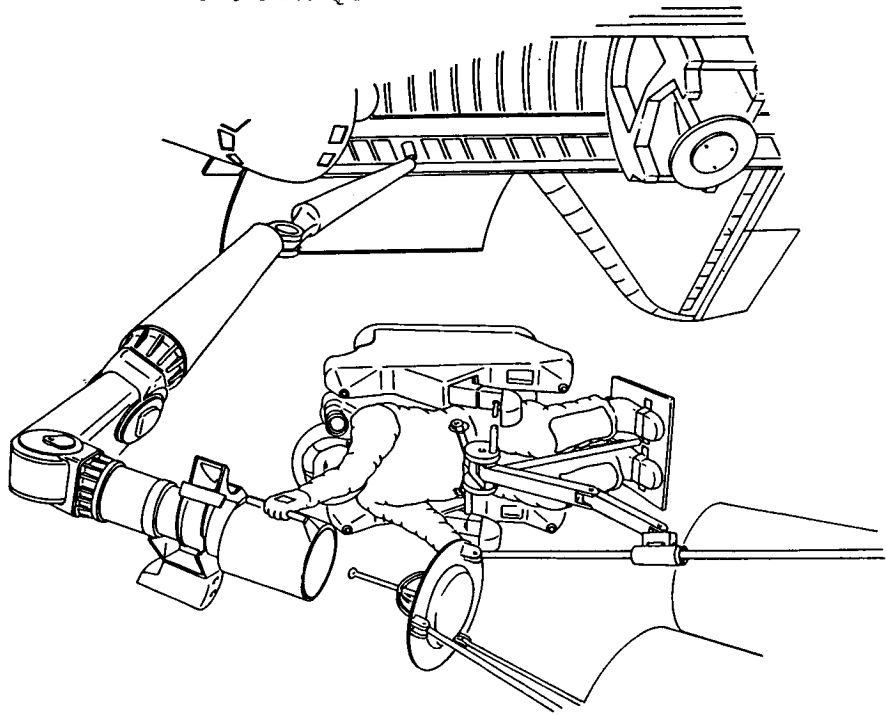
- PROVIDES UNENCUMBERING, REAL TIME EVA SYSTEMS MANAGEMENT
- PROVIDES REAL TIME AUDIO, VISUAL DATA UPLINK
- PROVIDES DISPLAY OF PREPROGRAMMED DATA



POWER ASSISTED GLOVE END EFFECTOR



GENERIC WORK STATION



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TELEOPERATOR HUMAN INTERFACE TECHNOLOGY

The main objectives of the teleoperator human interface technology program performed at the Jet Propulsion Laboratory in FY 84 include: (1) evaluation of the effects of microgravity on force feedback teleoperation; (2) evaluation of time delay effects on bilateral teleoperation; and (3) verification of a second order mathematical model of the human operator, and the synthesis of compensatory control strategies.

Extensive experimentation, data collection and analysis were performed for a number of tasks at the JPL Teleoperators Laboratory. Experimental setup included the part simulation microgravity suspension system designed and installed in FY 83. The existing universal force reflecting hand controller was used in conjunction with new software that was developed for simulating the teleoperation tasks. New software was also developed for data collection and analysis. Data collection led to time domain (i.e., trajectory plots) and frequency domain (i.e., Fourier transforms) analysis. Statistical hypothesis testing using analysis of variance techniques was performed to deduce the significance of variations in the results attributable to experimental factors such as individuals and parameter settings.

Conclusions on the microgravity effects on bilateral teleoperation included the verification of the second linear mathematical model for the human operator for most of the subjects. Specifically, results pointed towards the utility of damping (in the force feedback control loop of the hand controller used by the operator) to improve the stability of teleoperation in the presence of force disturbances and trajectory discontinuities. The extra damping was concluded to be beneficial to microgravity operations in most cases.

Time delay effects in teleoperation, particularly bilateral force feedback teleoperation, proved to be detrimental when the delay is in the order of a second (as used in the preliminary experiments). The use of graphics displays for the forces and torques generated in the control process was shown to be helpful in stabilizing the performance.

Conclusions pointed towards the use of more sophisticated control techniques, such as predictive control and displays, for the time delay problem. The disparity between subject reaction to damping in microgravity teleoperation will be investigated in FY 85. In addition, experiments on teleoperation aided by automatically articulated camera views will be performed to evaluate the human operator's reaction to stereo camera techniques, varying point-of-regards, and/or other viewing conditions.

TECHNICAL CONTACT: Antal Beczcy, JPL, (818) 354-2726
Edwin Kan, JPL, (818) 354-2726

TELEOPERATOR HUMAN INTERFACE TECHNOLOGY

1984 ACCOMPLISHMENTS

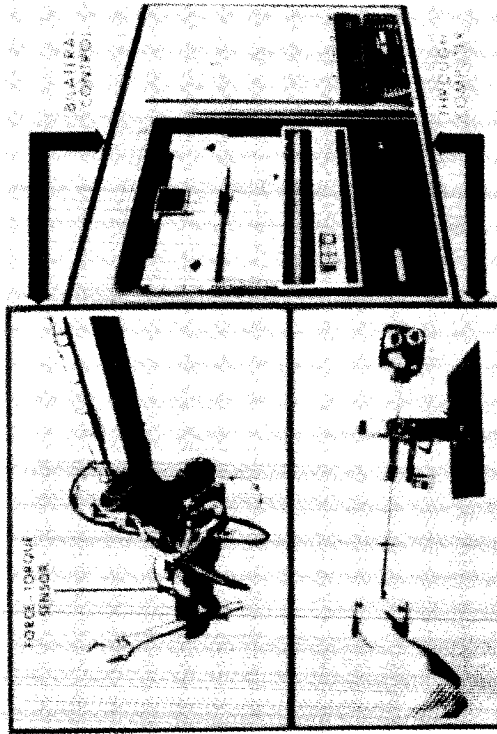
CONTROLS

- EFFECT OF (1) WEIGHTLESSNESS ON HUMAN ARM AND (2) TIME DELAY IN MANUAL FORCE-REFLECTING TELEOPERATOR CONTROL HAS BEEN EXPERIMENTALLY EVALUATED
- TECHNIQUES HAVE BEEN DEVELOPED TO COMPENSATE THE ADVERSE EFFECTS OF HUMAN OPERATOR WEIGHTLESSNESS AND SHORT (1-2 SEC) TIME DELAY IN MANUAL FORCE-REFLECTING TELEOPERATOR CONTROL
- AN ADJUSTABLE IMPEDANCE CONTROL MODEL AND PROCEDURE HAS BEEN DEVELOPED TO MATCH TASK AND HUMAN OPERATOR PERFORMANCE REQUIREMENTS IN MANUAL FORCE-REFLECTING TELEOPERATOR CONTROL

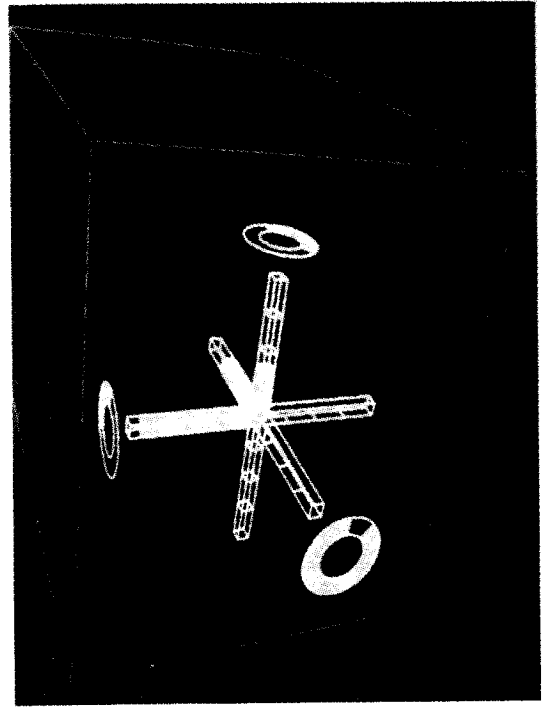
- HAND CONTROLLER TECHNOLOGY FOR TELEOPERATOR CONTROL HAS BEEN EVALUATED AND NEW DESIGN CONCEPTS DEVELOPED FOR COMPUTER-AIDED COOPERATIVE AND DEXTEROUS TELEOPERATION

DISPLAYS

- NEW DISPLAY FORMATS HAVE BEEN DEVELOPED USING HIGH-POWER COMPUTER GRAPHICS TO DISPLAY COMPLEX NON-VISUAL FORCE-TORQUE SENSING INFORMATION TO HUMAN OPERATOR IN TELEOPERATION
- COMPUTER GRAPHICS HAS BEEN DEVELOPED FOR EXPERIMENTAL SIMULATION STUDIES OF (1) FORCE-REFLECTING TELEOPERATOR CONTROL AND (2) CONTROL OF DEXTEROUS END EFFECTORS IN TELEOPERATION
- EXPERIMENTAL STUDY HAS BEEN INITIATED FOR VISUALLY-COUPLED DISPLAY SYSTEMS IN TELEOPERATION



GENERALIZED FORCE-REFLECTING CONTROL



ADVANCED GRAPHICS DISPLAY OF FORCES AND TORQUES

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CREW WORKSPACE DESIGN

Design of the crew's workspace is a major factor affecting human productivity. Workspace design must analyze the roles of humans in space and allocate room and equipment to permit the crew to perform these functions efficiently. New concepts to satisfy the requirements for spacecraft are required.

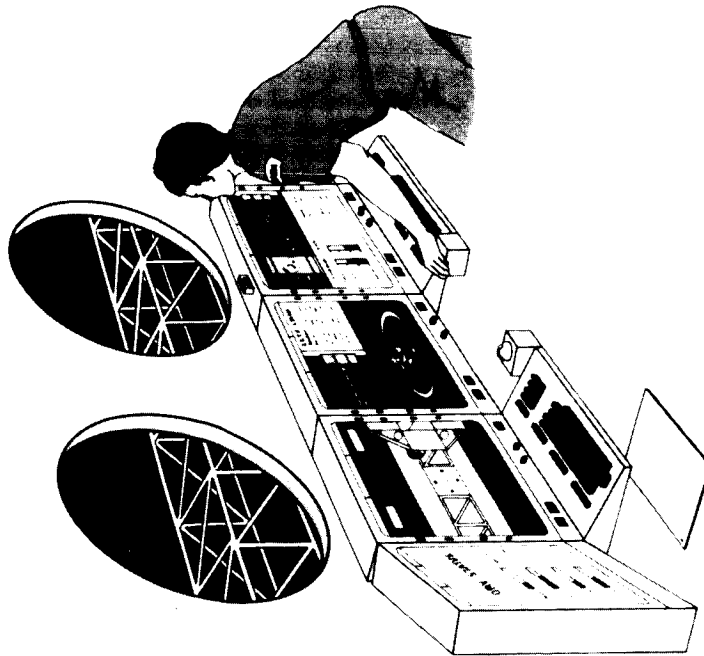
Space Station design requirements include access to outside walls, transportability of modules into and out of cylinders and capability for reconfiguration. The opposite line drawing shows a view of a habitat module arranged by the central beam concept. The beam running through the module carries utilities--power, water, air. The cylinder walls are accessible for maintenance and for repair in response to space debris or micrometeoroid penetration. All modules--storage, galley, work consoles, etc.--attach to the central beam. The central beam concept meets the design requirements in a novel manner. More efficient man/machine interactions result from designs which optimize the role of man in the system.

Displays and controls for the work stations are changing rapidly due to advances in electronics. A research plan for evaluating the characteristics of new displays and controls has been developed and is being implemented. Work stations are designed to be modular and easily reconfigurable, as shown in the opposite figure. This design will meet the man/system requirements being formulated for growth capabilities in future spacecraft.

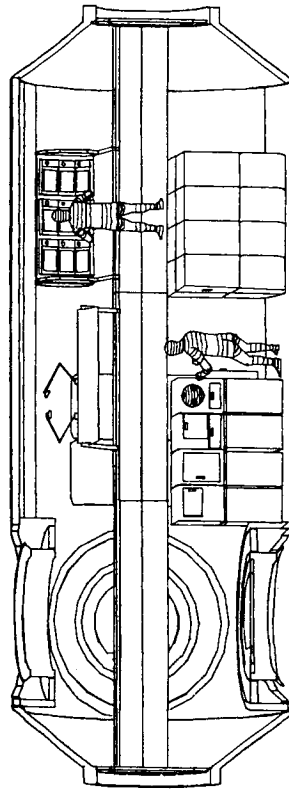
TECHNICAL CONTACT: Marianne Rudisill, JSC, (713) 333-6148

CREW WORKSPACE DESIGN

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PROXIMITY APPARATUS
WORKSTATION CONCEPT



HABITAT MODULE CONCEPT

COMPUTERIZED HUMAN MODELING

The thrust of the human modeling effort is to develop computerized tools for the designer which will present him or her with human factors data early in the design cycle. The three-dimensional body mapping system will generate a computer image of a human body in a fraction of a second. This will provide the designer with a detailed description of an individual that can be integrated into layouts for crew stations, work areas, passageways, etc. Contours describing the crewmember's reach envelope can be added to the image, allowing the designer to verify that controls can be reached. Information on force capabilities within the reach envelope is also needed. Ways of presenting force data graphically to the designer are being evaluated.

The body mapping data is acquired by projected beams of light onto a body and examining the reflections caught in a video camera. By coding the light beams, the location of the light source can be deduced, as shown in the opposite viewgraph (left photo). With this and the video data, real-world X, Y, Z coordinates can be calculated in less than a minute. A graphical rendition of a body at a workstation is shown in the viewgraph (right side). One concept for displaying force data is to color the workstation according to the force capability available at a given location.

The design cycle of a workstation, a spacecraft, or any other system designed for human interfaces will be reduced by automated design tools. Simulations of people working in the system can replace a set usually performed by the construction of mockups and having people try to work in it. A better fit with human capabilities will be the result of this work. Accurate data on the size and shape of people who will use the system is essential to good design. The body mapping system will provide this data; with further refinements, it will also produce this data in real time, giving a good description of human motion. Based on the use of body mapping techniques, simulations of strength and motion will be available to the designer during all design stages.

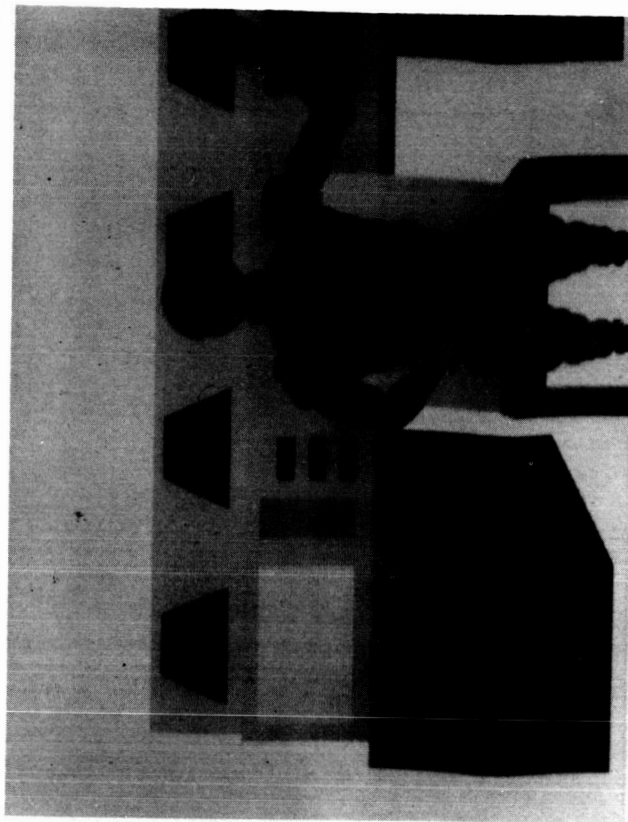
TECHNICAL CONTACT: Barbara Woolford, JSC, (713) 483-4065

COMPUTERIZED HUMAN MODELING

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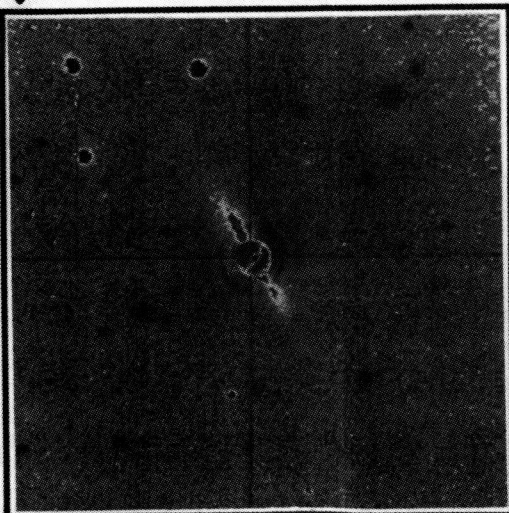
3-DIMENSIONAL LASER
BODY-MAPPING SYSTEM



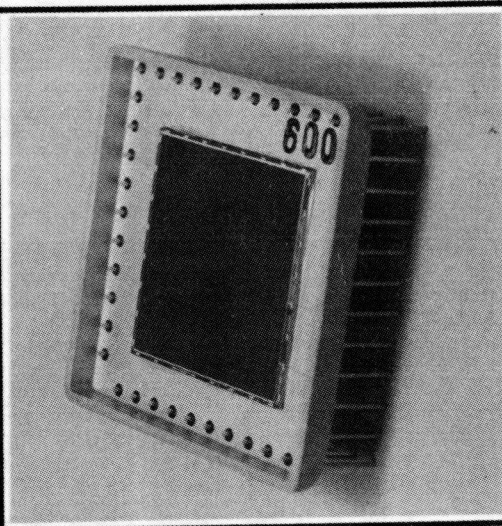
HUMAN MODEL IN COMPUTER
ASSISTED (CAD) SYSTEM

SCIENCE RETURN FROM OAST R&T

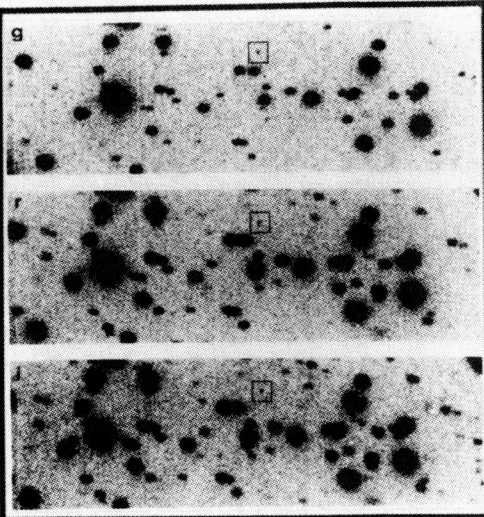
FIRST OBSERVATION OF
SOLAR SYSTEM
OUTSIDE MILKY WAY



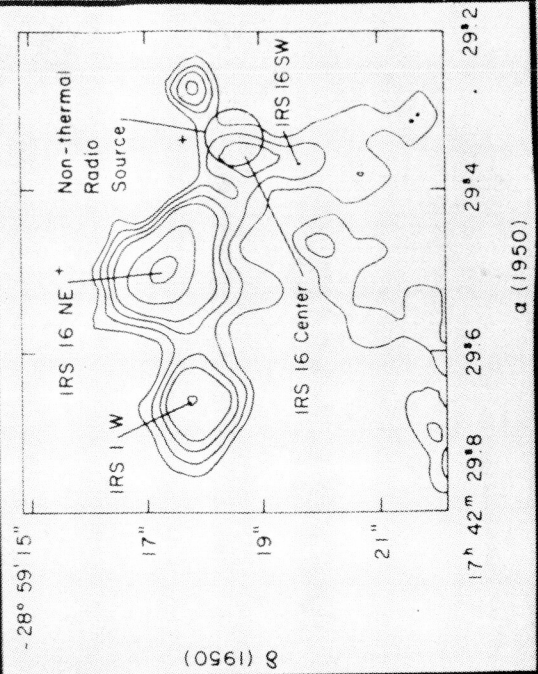
OAST SPONSORED
CCD RESEARCH



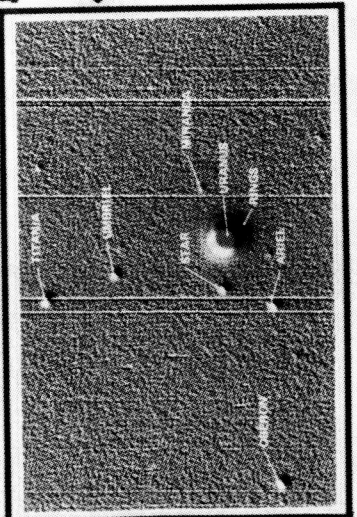
FIRST SIGHTING OF HALLEY'S
COMET 1985 APPARITION



FIRST OBSERVATION OF
IR SOURCES IN GALACTIC CENTER



FIRST PHOTO OF
RINGS OF URANUS



SENSOR TECHNOLOGY

The overall objective of the Sensor Technology Program is to provide new technology that exploits the unique properties of lasers, the capabilities of microwave tubes, and infrared detectors for passive and/or active sensing of terrestrial, planetary, and galactic environments.

Major sub-elements include technology development in the areas of linear, infrared, and x-ray detectors, sis detectors, large silicon CCDs, synthetic aperture radar, laser heterodyne spectrometer, infrared and UV/visible LIDAR. Potential uses include science and applications missions, space platforms, Space Station, and commercial satellite applications.

PROGRAM MANAGER: Dr. Martin M. Sokoloski
NASA/OAST/RC
Washington, DC 20546
(202) 453-2864

EXCIMER UV LASER

Active UV/VIS laser sensing of atmospheric physical parameters and species will play an increasing role in NASA's measurement program. A key technology driver for a space-based Lidar is the reliable and efficient operation of the laser system at high pulse energy. Progress in developing ultraviolet excimer laser sources for NASA missions this year included:

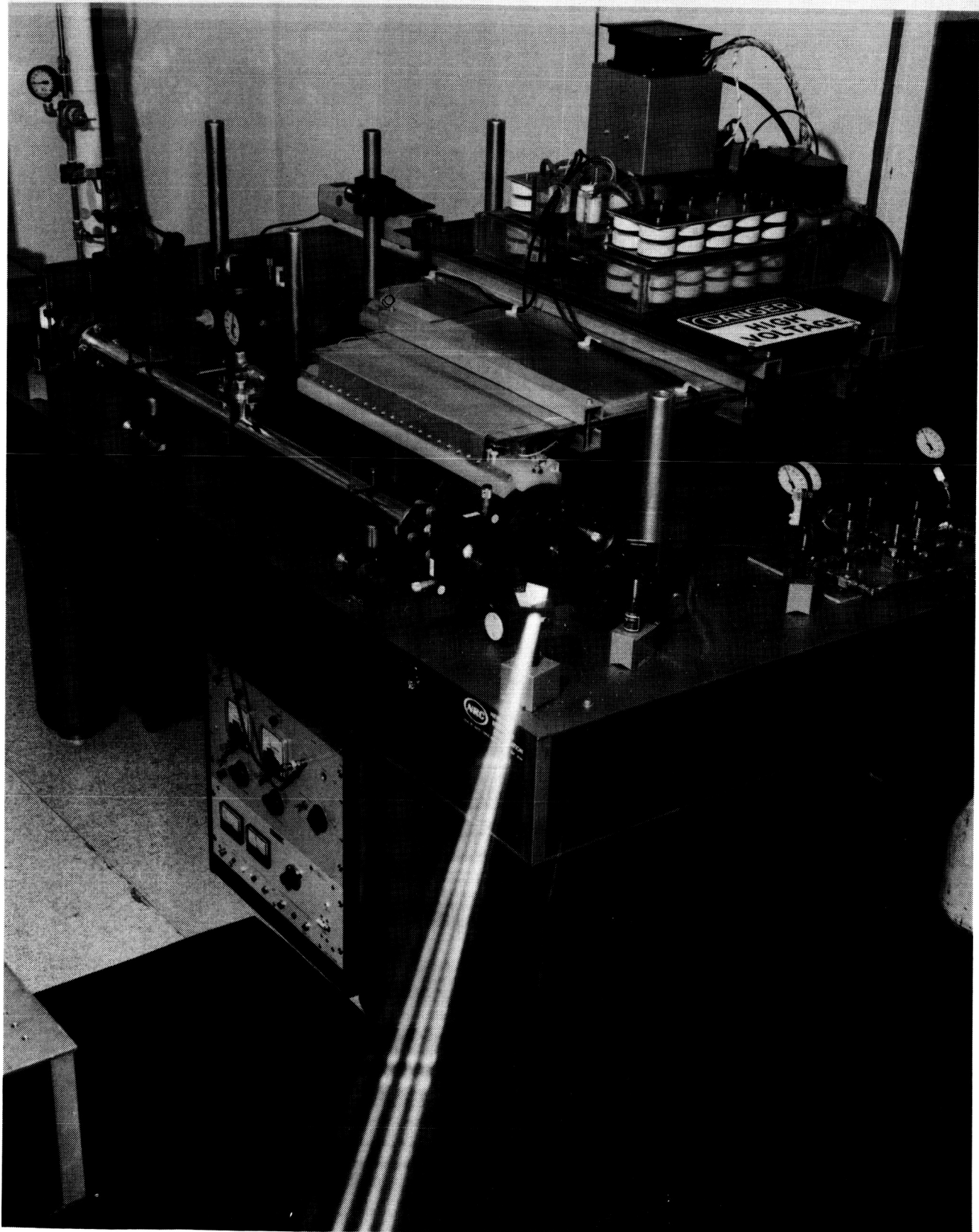
- o Demonstrated a 40 Hz, 0.1 J/pulse XeCl oscillator-amplifier laser system incorporating magnetic switches patented at JPL. This laser system has been operated routinely for over 10⁷ firings over the course of two years with no failure in the magnetic modulator. Proper implementation of the magnetic switches has resulted in low (~5%) electrical losses, proving that high efficiency long-lived electric discharge circuits can be built for a space-based laser.
- o First demonstration of a single mode XeCl laser with 25 MHz optical bandwidth. This bandwidth, along with the high atmospheric backscatter coefficient and high energy density eye safety threshold limit for the ultraviolet wavelength region, makes this laser system an attractive wind velocity Lidar candidate.
- o First demonstration of continuous narrow bandwidth (3 GHz) tuning of an XeCl laser in the 307.5 to 308.5 nm region for laser-induced-fluorescence detection of hydroxyl (OH) radicals.
- o Demonstrated two color laser ionization detection of NOx with an excimer laser.
- o Demonstrated a high energy magnetically switched XeCl laser with Raman shifting as proposed for ground-based upper atmospheric ozone DIAL Lidar measurements. The opposite figure shows the multiwavelength operation of a Raman shifted XeCl laser system. This laser was demonstrated with magnetic switches and tailored to the 308 nm region with a narrow 25 MHz optical bandwidth for laser-induced-fluorescence detection of hydroxyl (OH) radicals. The lifetime of the lidar depends on the discharge switch. The development of the magnetic switch greatly extends the lifetime of the system, thereby making it practical for space application.

The demonstration showed the viability of excimer lasers in a stratospheric ozone detection. The ozone detection instrument would use a coherent, Raman shifted beam with measurements at 308 nm, 353 nm and 400 nm to measure the on ozone line, off ozone line and atmospheric aerosol content at the same regions, and thus eliminate the need for three different lasers to be synchronized.

TECHNICAL CONTACT: James B. Laudenslager, JPL, (818) 354-2259
Thomas J. Pacala, JPL, (818) 354-3256

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EXCIMER UV LASER



PUSHBROOM RADIOMETRY

The Pushbroom Microwave Radiometer (PBMR) is a wide swath, digital noise feedback, precision calibrated instrument with a sensitivity and resolution appropriate to the aerial mapping of soil moisture. Several beams are arranged across the ground track of the sensor platform, thus affording a wide swath made up of many high resolution cells. The PBMR has been successfully installed in both three and four beam configurations on several aircraft types.

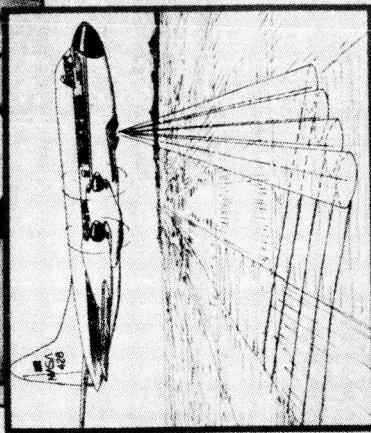
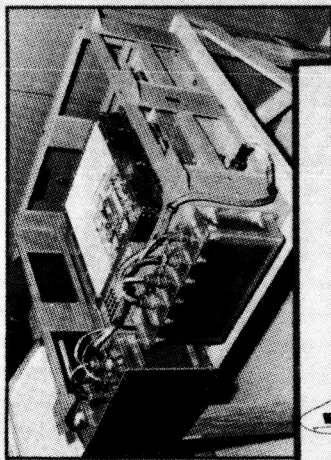
Since its initial check flight in 1983, the PBMR has completed numerous data missions over agricultural areas of widely varying characteristics. These have included cultivated fields in Maryland, Delaware, Texas and California, and swamps and forests in Virginia. Typically, a field is overflown by the width of the swath. The brightness temperature data from the individual beams are then processed and displayed on a two-dimensional false color map (lower center). The area represented here is made up of 13 USDA controlled fields on Maryland's Eastern Shore. The small squares on the lower plot are each positioned according to footprint location and colored to indicate radiometric brightness temperature, and thus relative soil moisture.

The pushbroom concept is equally valid for orbital use. A stated mission requirement for the Earth Observing System is the worldwide measurement of terrestrial soil moisture at 10 km resolution. In this context, the PBMR may have applications to meteorology, climatology, hydrology, water resource management and agriculture. A Space Station technology development mission experiment for passive microwave remote sensing, which could utilize a 100 m deployable antenna and multiple radiometers in a pushbroom configuration, is presently under study to satisfy the swath and measurement cell resolution requirement. It has been determined that the addition of a single infrared frequency would allow the measurement of the physical surface temperatures of land and oceans, and of ocean surface salinity.

TECHNICAL CONTACT: Dick Harrington, LaRC, (804) 865-3631

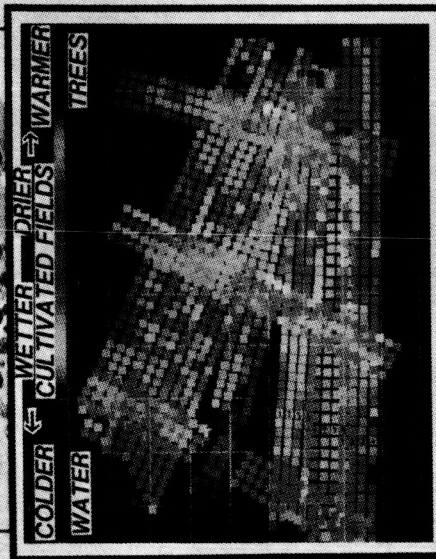
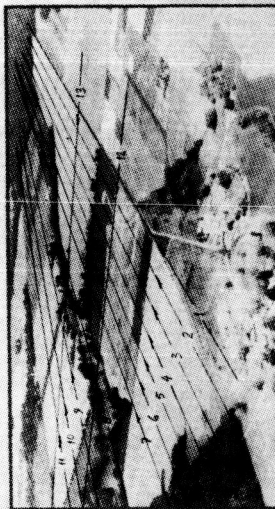
MICROWAVE REMOTE SENSING

RADIOMETRY



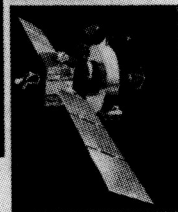
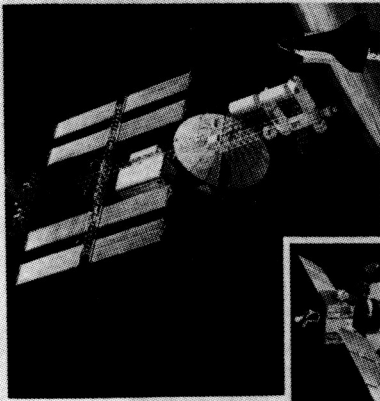
TECHNOLOGY CHALLENGE

- MULTIPLE RADIOMETER (PBMR)
- SENSOR DEVELOPMENT
- ACCURATE CALIBRATION METHODS
- DIGITAL SIGNAL PROCESSING
- ANTENNA PATTERN CORRECTION



TESTING/VERIFICATION

- BRIGHTNESS TEMPERATURE VERSUS SOIL MOISTURE
- MULTIPLE SENSOR FLIGHT TEST PROGRAM



FUTURE APPLICATIONS

- SOIL MOISTURE
- GLOBAL MAPPING
- SEA SURFACE TEMPERATURE/SALINITY

DIODE ARRAY TECHNOLOGY

The objective of this program is to define, develop, and evaluate advanced semiconductor laser diode arrays for application in all solid state laser systems for remote sensing from space. One of the key recommendations of a recent NASA workshop (hosted by Stanford University) on tunable solid state lasers for remote sensing was to develop long lifetime diode array pumps for solid state lasers.

Key to the use of laser remote sensing in space is the development of all solid state laser and lidar systems. Conventional flashlamp pumps must be replaced by more efficient and reliable pumps in order to meet the power consumption and lifetime requirements imposed by space operation. Laser diode arrays offer the only known substitute that can effectively meet these critical requirements of advanced, tunable, all solid state laser and lidar systems for operation in space.

LaRC has been a leader in the support of the development of semiconductor laser diode technology development. In the early 1970s, LaRC initiated a program to develop semiconductor laser materials growth and state-of-the-art laser diodes. The results of this program have been shared with other NASA Centers. This effort has resulted in many accomplishments, such as the demonstration of a 40 MW, single-mode CW, CDH-LOC laser diode and more recently the demonstration of a 300 MW, CW linear diode array and a channeled-substrate phased array. In addition, LaRC continues to support research and development of diode pumped Nd:YAG lasers and amplifiers at Stanford University. This work has had applications in remote atmospheric sensing which has been responsible for the invention of the miser laser, the realization of a narrow linewidth low power Nd:YAG laser and the realization of a narrow linewidth low power Nd:YAG oscillator.

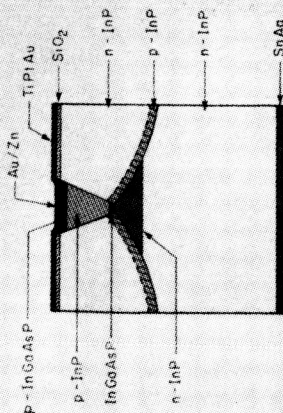
Linear and circular arrays composed of individual laser diodes have been available for many years. The operational characteristics of individual laser diodes are well documented. Monolithic linear and two dimensional arrays are presently in the laboratory stage of development. These monolithic linear arrays have already been demonstrated as being capable of emitting 300 MW of CW power. A goal of this program is the development of two dimensional arrays which emit more than 1 Joule. These devices have application as pump sources for all solid state laser systems for remote atmospheric sensing in space.

TECHNICAL CONTACT: Herb Hendricks, LaRC, (804) 865-3777

DIODE ARRAY TECHNOLOGY

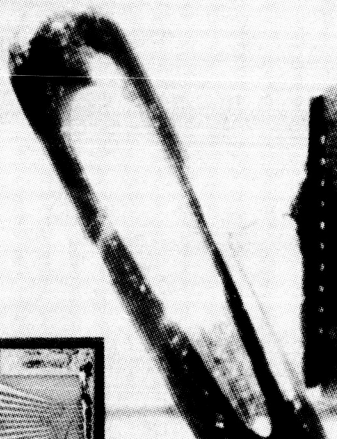
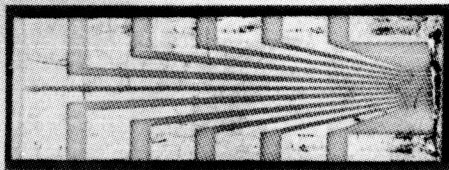
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LASER DIODES

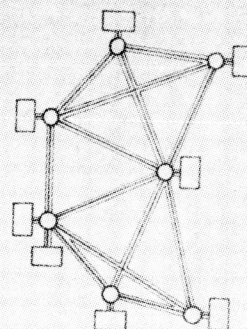
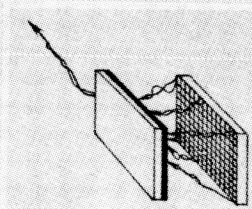
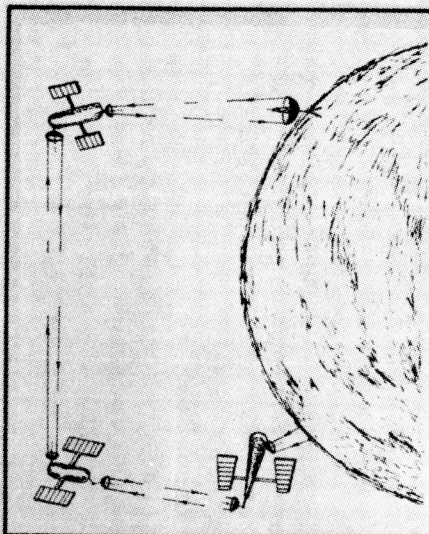


- 40 MW LASER DIODE PUMP DEMONSTRATED

LASER DIODE ARRAYS



- 10 ELEMENT 300MW CW DIODE ARRAY DEMONSTRATED



FUTURE IMPROVEMENTS

- EFFICIENCY
- OUTPUT POWER
- WAVELENGTH STABILITY
- LIFETIME/RELIABILITY

BENEFITS/PROGRAMS

- ALL SOLID STATE LIDAR
- SPACE COMMUNICATIONS
- PROXIMATELY OPERATIONS
- OPTICAL DISK STORAGE

IMAGING X-RAY SPECTROMETER

The Imaging X-Ray Spectrometer is a solid-state silicon detector using "deep diodes" through the wafer formed by thermomigration of aluminum. Thermomigration is a method in which temperature gradient diffusion is used to drive aluminum posts through a silicon substrate with a lateral spread of a few percent (less than 5%) of the substrate thickness. The first such x-ray detectors were designed, fabricated, and tested at the Goddard Space Flight Center.

The detector array is unique because it offers both good energy and spatial resolution for the analysis of x-rays in the 1 to 30 keV range. Because the aluminum posts go completely through the detection substrate, the complete thickness of the wafer can be depleted, leading to high quantum efficiencies for x-rays in the 1 to 10 keV range. The quantum efficiency is a function of the silicon thickness; a quantum efficiency of 98% has been achieved at 10 keV.

The thickness of the wafers to be used is only limited by the ability to drive posts because depletion voltages are now independent of substrate thickness. To date, good posts have been driven through 1300 micrometer wafers. Spatial resolution is attained by forming a grid structure surrounding individual thermomigrated aluminum posts. In the middle of each pixel is a post which forms the electron collection terminal for the individual pixel. An array of greater than 100 pixels, 1 mm^2 per pixel, is planned for the AXAF mission.

The critical parameter of interest is the noise level of the detector system. This noise level is measured by utilizing a Pulse Height Analyzer (PHA) spectrum of the 5.9 keV Mn alpha line. The Full Width Half Maximum (FWHM) of the peak (in eV's) is considered the noise level for the detector system. Total noise has dropped from 2.25 keV in the early stages of research to our present value of about 250 eV. Of this 250 eV, about 190 eV was due to the detector while about 150 eV was due to the electronics. Improvements in on-chip integration of electronics and detector arrays should reduce system noise levels. Process and material changes are expected to further reduce the noise level of the detector. On-chip integration of the electronics is being performed by CAD of amplifier systems in NMOS silicon gate technology to attack the electronics noise level.

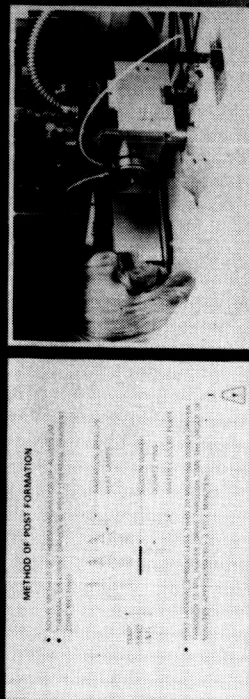
An important factor is the available pixel size. Detector development using 7000 ohm-cm material has increased the pixel size so it is no longer a problem. The 700 micron pixel size described is readily obtained at voltages of 100 volts. Research is continuing to further reduce system noise levels and provide maximum integration.

TECHNICAL CONTACT: George Alcorn, GSFC, (301) 344-5374

IMAGING X-RAY SPECTROMETER (For 1 to 30 KEV X-rays)

NOVEL TECHNOLOGY

- THERMOMIGRATION OF AL



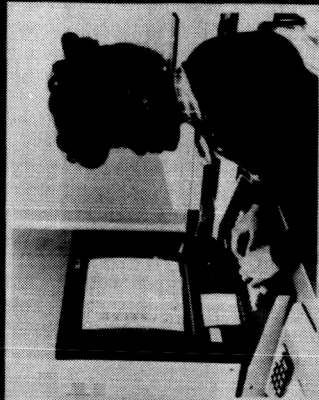
METHOD OF POST FORMATION

- Novel method of thermomigration of Al used for forming Al-Al₂O₃ barrier layer on SiO₂ substrate.
- This method provides the highest efficiency, low noise, and low cost.
- This method provides the highest efficiency, low noise, and low cost.
- This method provides the highest efficiency, low noise, and low cost.

KEY FEATURES

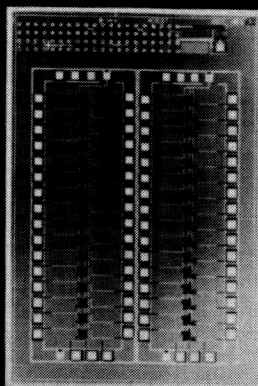
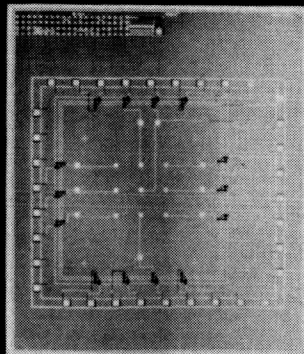
- "DEEP DIODES", AL POSTS COMPLETELY DRIVEN THROUGH 500 MICRON SILICON WAFER
- LATERAL SPREAD LESS THAN 20 MICRONS
- COMPLETELY DEPLETED PIXELS
- EXCEPTIONALLY HIGH QUANTUM EFFICIENCY

INTEGRATED CIRCUIT ELECTRONICS



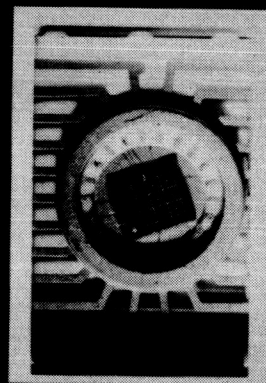
KEY FEATURES

- ON CHIP ELECTRONICS
- LOW NOISE
- HIGH GAIN
- RELIABILITY
- LOW POWER OPERATION
- CUSTOM DESIGNED BY CAD TECHNIQUES AND FABRICATED
- IN NMOS SILICON GATE
- IN CMOS TECHNOLOGY
- INDIVIDUAL AMPLIFIERS FOR EACH PIXEL



IMAGING X-RAY ARRAY SYSTEM

- DETECTOR ARRAY SHOWN BELOW



KEY FEATURES

- EXPANDABLE MULTI-PIXEL TECHNOLOGY
- FWHM NOISE LEVEL CURRENTLY 250 EV (WORK PROCEEDING TO LOWER NOISE LEVEL)
- EXCELLENT QUANTUM EFFICIENCY - 98% AT 10 KEV
- VARIABLE SIZE FULLY DEPLETED PIXELS - PIXEL SIZE VARIABLE FROM ABOUT 40 MICRONS TO OVER 1 MM
- IDEA ORIGINATED AND DEVELOPED "IN HOUSE" AT NASA-GODDARD
- PATENT GRANTED 1984

LASER HETERODYNE SPECTROMETER

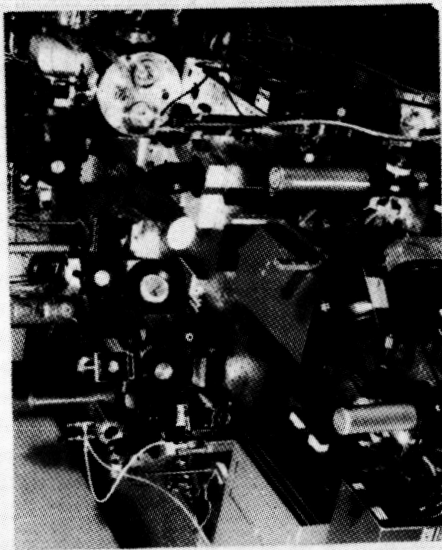
The laser heterodyne spectrometer (LHS) was developed from a LaRC conceptual design as a demonstration of current techniques in the application and control of tunable diode lasers (TDLs) as heterodyne local oscillators for remote sensors. The TDL imposes exacting requirements in instrument electronics, cryogenics, electro-optics, microwave techniques and computer applications.

A two channel brassboard was constructed; this instrument was used to demonstrate the detection of atmospheric ozone using TDLs. Measurements were made in Hampton, Virginia at sea level using a solar signal directed by a solar tracker. The TDL local oscillator provided both tunability and very high resolution (10^{-4} cm^{-1}). The instrument was designed to make ground measurements, and could also be mounted aboard NASA's CV-990 flight laboratory.

The LHS was integrated for van operation and transferred to Colorado for use by the University of Denver. It will be used to acquire supportive atmospheric transmission absorption data in the 9 to 11 micron spectral region. Other applications include trace species and auroral measurements.

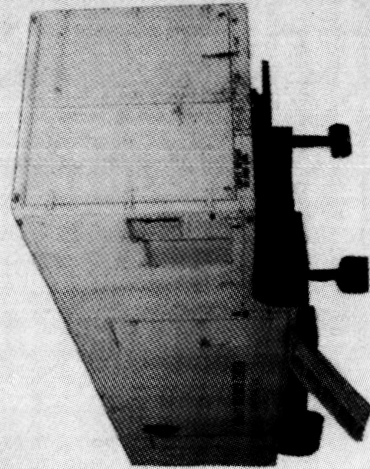
TECHNICAL CONTACT: Steve Katzberg, LaRC, (804) 865-4469

LASER HETERODYNE SPECTROMETER



BRASS BOARD BUILT AND DEMONSTRATED

- VERY HIGH RESOLUTION DATA OBTAINED (10^4 cm^{-1})
- COMPUTER CONTROL OF TDL TEMPERATURE, CURRENT AND WAVELENGTH IDENTIFICATION
- TWO CHANNELS OPERATED SIMULTANEOUSLY
- OPERATION FROM 9 TO $11 \mu\text{m}$

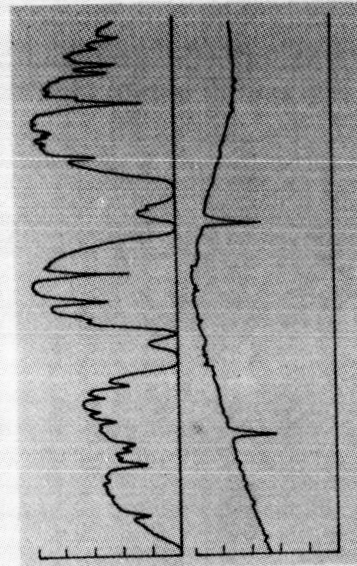


APPLICATIONS:

- ATMOSPHERIC STUDIES
- HIGH RESOLUTION TRANSMISSION MEASUREMENTS
- AURORAL MISSIONS

COMPONENT DEVELOPMENT AND INSTRUMENT DESIGN

- TUNABLE DIODE LASERS DEVELOPED FOR LOCAL OSCILLATOR
- COOLER & CURRENT CONTROL REFINEMENTS TAILORED FOR INSTRUMENT APPLICATIONS
- WAVELENGTH IDENTIFICATION TECHNIQUES DEVELOPED



COHERENT CO₂ DOPPLER LIDAR

The Coherent Doppler Lidar is used for measurements of accurate velocities for environmental/meteorological and aeronautical wind fields and space station rendezvous and proximity operation. Advancements in this technology require the development of high frequency stable narrow bandwidth lasers over a range of pulse energies up to 10 Joule/pulse. LaRC has pioneered two key approaches for attaining these goals involving control of the frequency stability and bandwidth of high pulse energy CO₂ lasers through use of low energy lasers, whose output is then used for injection locking or power amplification to higher pulse energies.

First, a low energy, 0.05 Joule/pulse, 2 pps injection controlled CO₂ ring laser was developed for on- and off-line center operation, as applicable to aerosol and Doppler Lidar (winds) and Tunable Differential Absorption Lidar (trace gases). A 1 Joule/pulse, 20 pps master oscillator power amplifier (MOPA) now is under development with high frequency stability, long pulse duration and far field pattern well suited for coherent Doppler Lidar velocity measurements. Since the high pulse energy MOPA output is largely controlled by the low pulse energy master oscillator, a unique approach providing considerable cost reduction was tried by using a contractually developed new master oscillator. The power amplifier was converted from a commercial Lumonics laser.

The performance of the 1 Joule/pulse, 20 pps CO₂ MOPA is being checked against a theoretical model to develop scaling relations needed for the design of a 10 Joule/pulse, 10 pps CO₂ lidar for satellite based global wind velocity measurements.

TECHNICAL CONTACT: Robert Hess, LaRC, (804) 865-2818

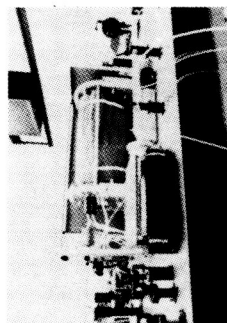
CO₂ DOPPLER LIDAR

TECHNOLOGY REQUIREMENTS:

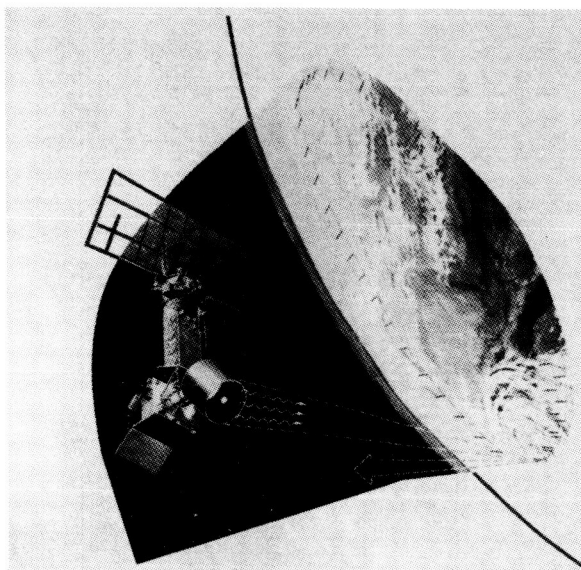
GLOBAL DOPPLER LIDAR
WIND VELOCITY
MEASUREMENTS WITH 1
TO 5m/SEC ACCURACY,
1 KM VERTICAL AND 100
TO 250 KM HORIZONTAL
RESOLUTION

- A DOPPLER LIDAR
TO MAKE WINDS
MEASUREMENTS
- 1 m/sec ACCURACY
- 1 KM VERTICAL
RESOLUTION
- 100 KM HORIZONTAL
RESOLUTION

1 JOULE/PULSE - 20 P.P.S.
HIGH STABILITY
NARROW BANDWIDTH
MASTER OSCILLATOR



POWER AMPLIFIER
FOR HIGH VELOCITY
ACCURACY CO₂
DOPPLER LIDAR



- GLOBAL WINDS
MEASUREMENTS
- SPACE STATION
PROXIMITY OPERATIONS

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DEMONSTRATION OF InSb ARRAY TECHNOLOGY FOR SPACE ASTRONOMY

A program to demonstrate the potential for indium antimonide (InSb) technology for space applications has been successfully completed. This program was performed by taking advantage of a no-cost loan of an advanced integrated infrared (IR) detector array and a highly-capable group of university scientists. Under a University of Rochester grant, a 32 x 32-element array from Santa Barbara Research Center with integral charge coupled device (CCD) readout was evaluated, first in the laboratory and then on various telescopes, under moderate and low optical background conditions. The low-background testing simulated the conditions expected on the Space Infrared Telescope Facility (SIRTF).

Laboratory measurements indicate that the array had good quantum efficiency (about 60%), imaging characteristics, and well capacity (10^7 electrons). Readout noise levels below 1400 rms electrons were measured. Optimum operating conditions (temperature, clock and DC voltages, frame rates) were established. A progressive series of technology demonstrations under real observing conditions followed at the university's C.E.K. Mees Observatory 24 inch, the Kitt Peak National Observatory 50 inch, and the Infrared Telescope Facility 120 inch telescopes, respectively. These demonstrations produced two very significant findings: (1) excellent astronomical images of planets, star fields, and galaxies could be obtained, and (2) under a particular set of low-background operating conditions (2.2 micron), the average sensitivity of the 870 working pixels was a factor of 2 better than the existing discrete-detector instruments in use for ground based observing. Sources down to +17.5 magnitude could be observed with 6 min of on-chip integration time. The telescope tests also revealed performance characteristics such as "ghosting," which has not been previously identified in laboratory characterization. These demonstrations were so successful that scientific papers (on the structure of the nucleus of the M82 galaxy and on structure of the Galactic Center) are in preparation.

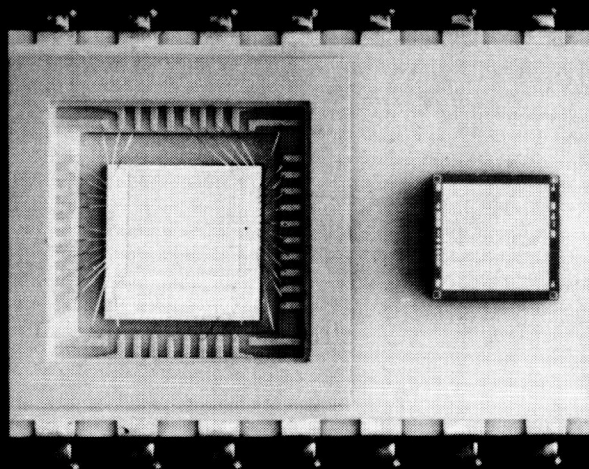
This effort proved the applicability of InSb under low-background astronomical conditions. It also provided the basis for the selection of an integrated InSb IR array for the baseline technology for one band of the selected SIRTF Infrared Array Camera.

TECHNICAL CONTACT: John H. Goebel/Craig R. McCreight, ARC, (415) 694-6549

INDIUM ANTIMONIDE (InSb) ARRAY DEVELOPMENT

UNIVERSITY OF ROCHESTER — LAB AND TELESCOPE EVALUATION
SANTA BARBARA RESEARCH CENTER — NO-COST LOAN OF 32 × 32 InSb CCD IR ARRAY

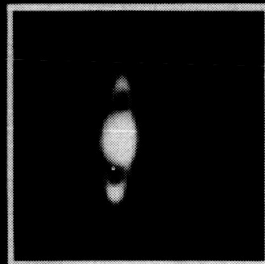
LABORATORY



CHARACTERIZATION AT U. ROCHESTER:
— 60% QUANTUM EFFICIENCY
— <1400 e⁻ READ NOISE
— EXCELLENT IMAGERY

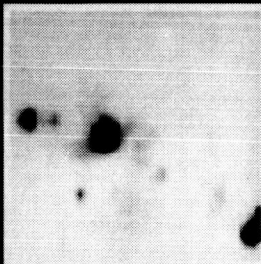
TELESCOPE DEMONSTRATIONS

AT MEES 24 in., KITT PEAK 50 in., IRTF 120 in.
— EXCELLENT IMAGES OF



PLANETS

SATURN



STAR FIELDS

BN IN ORION

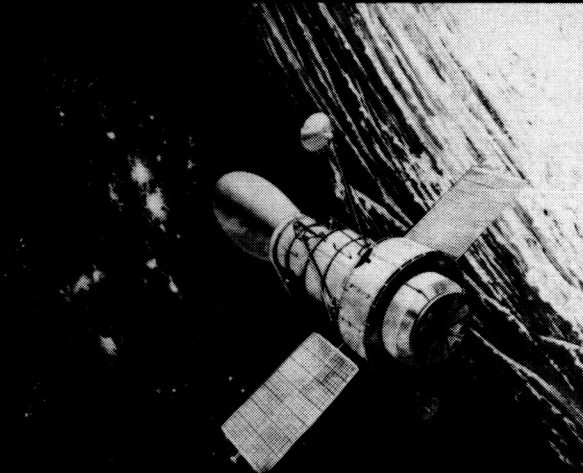


GALAXIES

M82

SENSITIVITY AT 2.2 μm: 2 × BETTER
(0.8 MAGNITUDES) THAN BEST DISCRETE
InSb DETECTOR INSTRUMENTS

SPACE



PROVES APPLICABILITY OF InSb ARRAYS FOR
SIRTF. SELECTED AS BASELINE ARRAY FOR
SIRTF INFRARED ARRAY CAMERA

PORTABLE ADIABATIC DEMAGNETIZATION COOLER

A portable adiabatic demagnetization (ADM) cooler has been developed as part of the ARC cryogenic program. The portable ADM cooler has been operated at temperatures down to 50 milli-Kelvin. Compared to the approximately 1.5 Kelvin currently available on IRAS, the Infrared Astronomical Satellite, and COBE, the Cosmic Background Explorer, the noise equivalent power (NEP) of a bolometer will be reduced by a factor of 5000 by operating at 50 mK. In Space Infrared Telescope Facility (SIRTF) application, this would make background limited observation in the 200-700 micron region possible.

The operating temperature of the cooler can be stabilized by a feedback loop that controls the final demagnetization. In addition, the cooler was designed for easy access and a fast turnaround, and also, its temperature can be easily controlled over a wide range of 50-500 mK.

The ADM cooler has been configured for a demonstration at Mt. Palomar during the 1984/85 winter. This will be the first time that an ADM cooler and IR detector module have been tested as a unit in an environment relevant to IR observation. To configure the module for this demonstration, the cooler first had to be miniaturized. The standard laboratory ADM cooler is about the size of a person. The ARC cooler was reduced to a package roughly two feet tall and one foot in diameter. This package includes the vacuum shell, insulation, and liquid helium precooling bath. The cooler is approximately the size that would be required for SIRTF. Included in the module are a bolometer and optics for sub-mm wave observation. The bolometers had to be developed at ARC because of the unique, low temperature application.

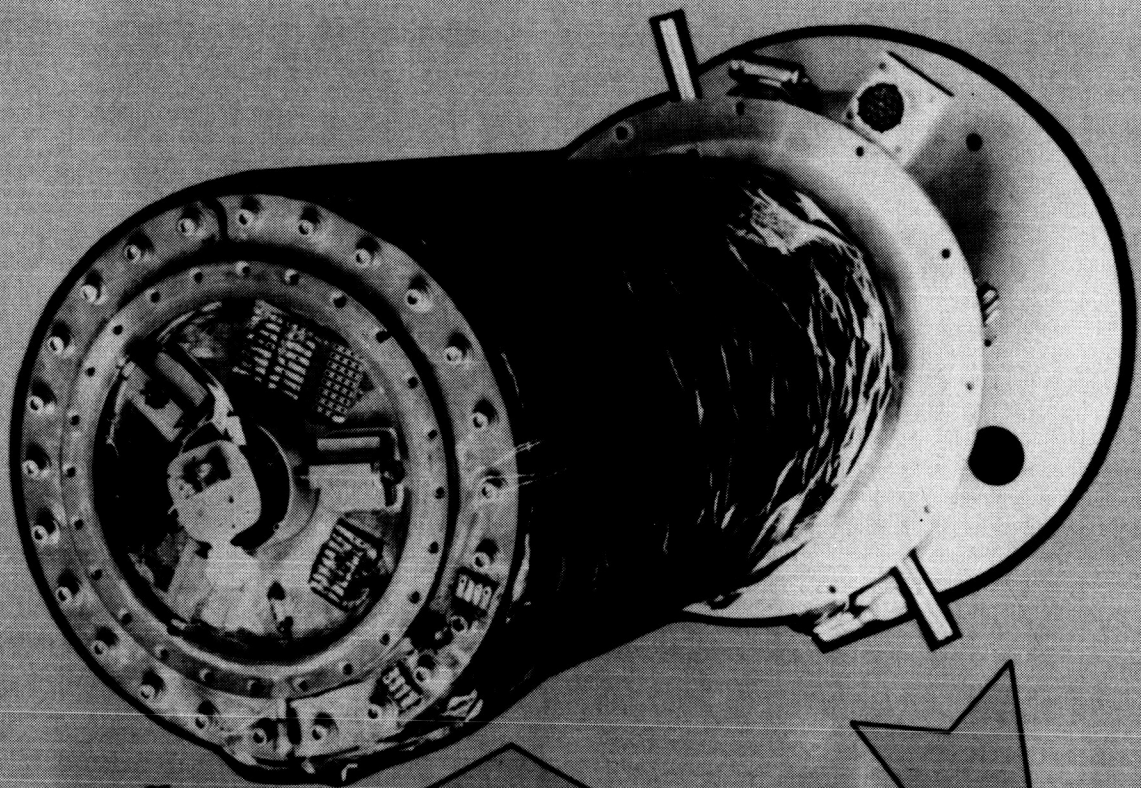
Once the usefulness of the module has been demonstrated, it will be used as a test bed for improved bolometers and optics that can make full use of the low temperature available. Such a test bed is needed because of the limited amount of work that has been done to develop a 200-700 micron instrument for SIRTF. This cooler will provide a relevant environment for SIRTF, which has chosen an ADM cooler because of the long wavelength module of its Multiband Imaging Photometer.

TECHNICAL CONTACT: Peter Kittel, ARC, (415) 694-6525

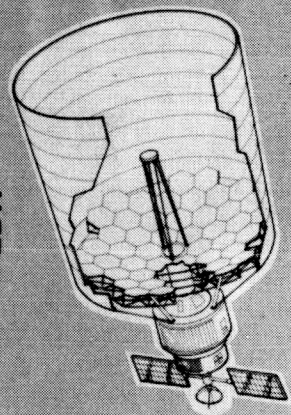
PORTABLE ADIABATIC DEMAGNETIZATION COOLER

- OPERATES DOWN TO 50 mK
- CONFIGURED FOR DEMONSTRATION AT MT. PALOMAR

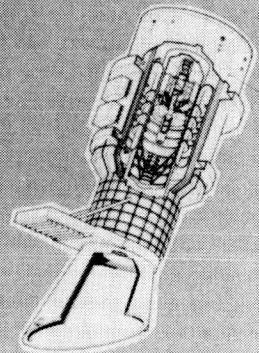
- DEMONSTRATION OF FAR IR
DETECTOR/COOLER MODULE
- TEST BED FOR SIRTf/LDR
200-700 μ m DETECTORS



LDR



SIRTf



MULTIFUNCTION SYNTHETIC APERTURE RADAR ANTENNA TECHNOLOGY

Significant progress has been made in identifying the information needs for understanding the processes that underlie the modifications on the surface of the Earth. These processes determine the global distributions and dynamics of biological productivity. The large and very frequent need for parameters for the biological predictive models has given impetus to remote sensing using Synthetic Aperture Radar (SAR) systems. The functional requirements for future SAR mission sets include swaths in excess of 150 km with multi-band, multipolarization, and multi-incidence angle capability having amplitude calibration to approximately 2.0 dB. New technology advancements are also needed for antennas capable of operating at several frequencies with electronic beam steering and multipolarization capability. The availability of this advanced SAR technology will allow the design of spacecraft SARs which will satisfy multimission objectives at substantial cost-savings. Earth and ocean resources surveys could be performed in the same mission.

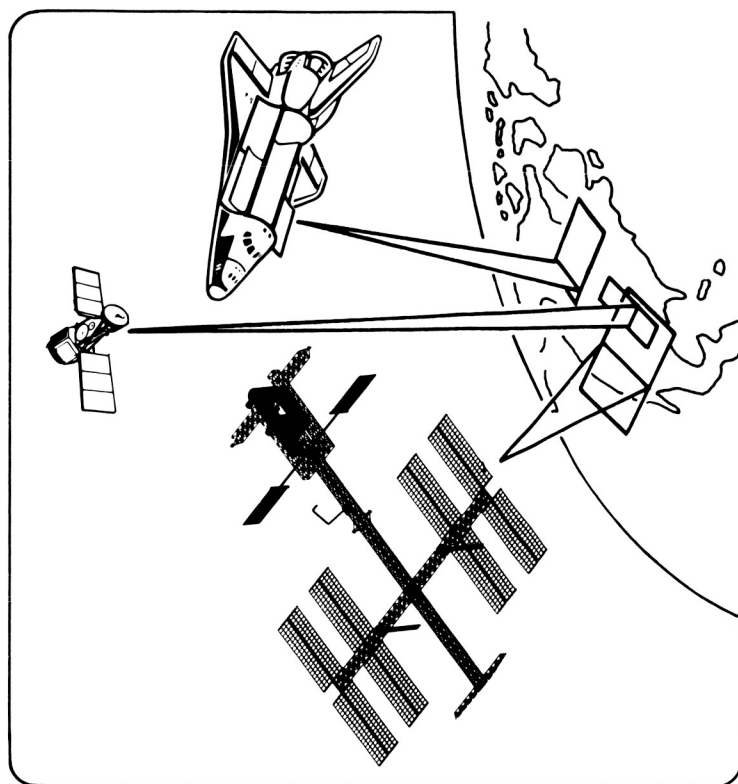
One approach to antenna technology is to first perform trade-off studies to identify the most feasible and efficient designs. Two designs have been identified as a result of these efforts, the microstrip distributed array and the interleaved waveguide array. In FY 84, a side-by-side microstrip antenna design was developed that can operate at L-, C-, and X-band frequencies. This antenna was implemented for the C-band frequency, and a breadboard of the C-band distributed array (12 x 18 elements) antenna has been developed. This breadboard is now being modified to incorporate distributed power design. After successful completion of this, a breadboard panel of L-, C-, and X-band antenna will be developed and tested.

The interleaved array antenna design concept has been developed for the L-, C-, and X-band antenna, and a survey of materials suitable for spacecraft design was completed. The application of graphite epoxy for the design was established through construction and testing of waveguide and feed components. These assembly techniques are now being demonstrated by fabricating a 5 x 5 array for the X-band. The future plan is to also develop a breadboard array at the L- and C-bands to verify the overall antenna design/fabrication feasibility.

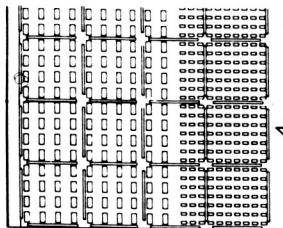
TECHNICAL CONTACT: Kumar Krishen, JSC, (713) 483-5518

SYNTHETIC APERTURE RADAR ANTENNA TECHNOLOGY

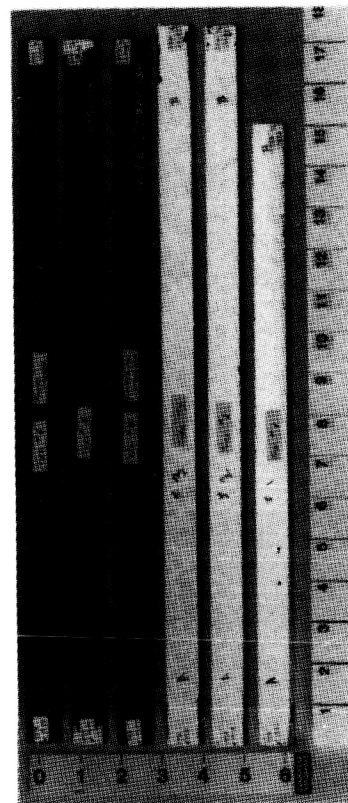
- MULTIMISSION
Reusable for Orbiter
- MULTIMODE
- COST EFFECTIVE
- HIGHLY RELIABLE
Important for Space Station and Satellites



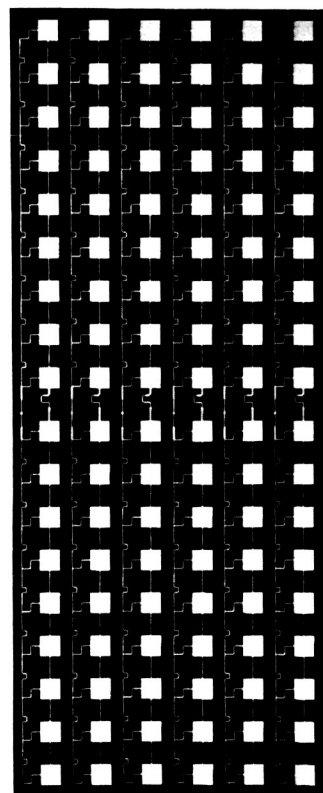
INTERLEAVED ARRAY



Design Concept for L-, C-, and X-Band



Metallized Graphite Epoxy Component Fabrication



MICROSTRIP ARRAY
C-Band Breadboard

DETECTION OF WIND SHEAR BY AIRBORNE DOPPLER RADAR

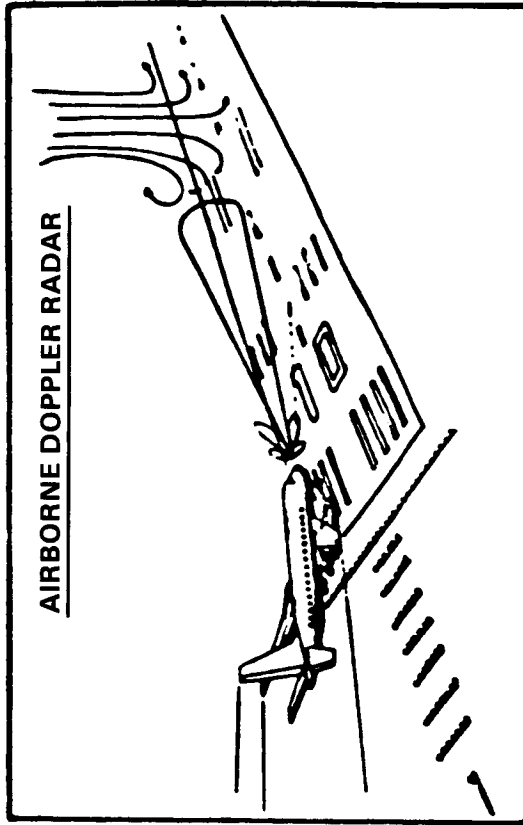
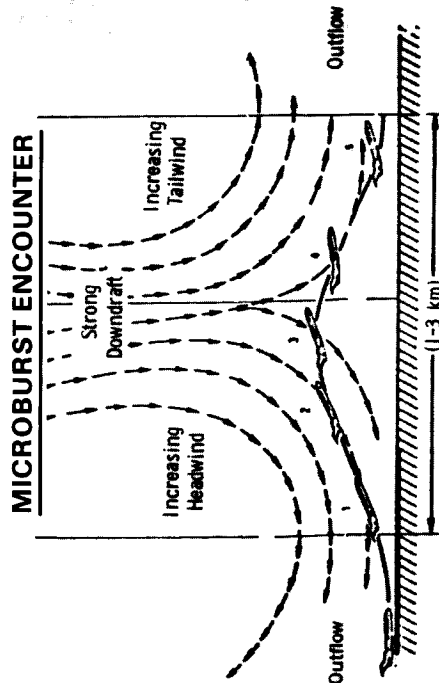
Severe low altitude wind shear remains one of the most serious hazards to aircraft. Research into the applicability of advanced airborne radar sensors for this hazard has been mandated by a committee of the National Research Council and by the FAA. Pursuant to this task, a joint NASA/FAA program has been defined, with work scheduled to begin in FY 85. The objective of this program is to advance the technology of airborne Doppler radar for the purpose of detecting low altitude wind shear and to research its applicability as a sensor for hazardous wind shear on takeoff and landing.

The program approach is to devise and develop suitable radar techniques and hardware and to conduct an experimental program to define the capability of airborne Doppler radars to address the wind shear hazard. The results of this work will be presented in the FY 85 annual report.

TECHNICAL CONTACT: Bruce Conway, LaRC, (804) 865-3601

AIRBORNE RADAR TECHNOLOGY FOR WIND SHEAR DETECTION

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PROBLEM

- WIND SHEAR—A MAJOR HAZARD
- ADVANCED WARNING REQUIRED

HERITAGE

- MEASUREMENTS OF WIND SHEAR DEMONSTRATED
- NO LOW ALTITUDE CAPABILITY

PROGRAM

- EXPLORE NEW TECHNOLOGIES
 - RESOLUTION
 - GROUND CLUTTER
 - SIGNATURE
- FAA SPONSORSHIP
- OBJECTIVE: A PRACTICAL AIRBORNE DETECTOR

CRRES TEST CIRCUIT

The CRRES test circuit was designed to evaluate fundamental device parameters that affect circuit performance in a space radiation environment. Twelve of these experimental circuits will be included among other commercial integrated circuits in the Combined Release and Radiation Effects Satellite (CRRES) to be launched in 1986. The experiment will provide an opportunity to study the effects of single event upset (SEU) and total dose radiation on devices fabricated using foundry processes. The test circuit contains three main functions: a timing sampler for measuring propagation delay through inverters, a 1 Kbit RAM for sensing SEU, and an array of transistors for extracting device parameters.

The timing sampler consists of a string of inverters through which a logic transition can be propagated under the control of external timing events. The number of inverter stages transitioned in a fixed timing interval is presented as a binary word and used to characterize the propagation delay. The static RAM is organized as a 64 by 16-bit word; it uses the familiar six-transistor cell as the memory element. The RAM will be used to evaluate SEUs as a function of the total dose radiation.

The transistor array contains 32 individually addressable transistors. A decoding scheme is used to address each transistor in order to minimize pinouts to the measurement system and thus maximize the amount of data that can be acquired by the system. The array contains 16 n-channel and 16 p-channel transistors of varying sizes and will be used to characterize the transistor parameters as a function of radiation dose.

Prototype devices have been successfully fabricated through several silicon foundries. Test results have verified that all functions are performing as expected. Currently, the circuit is being fabricated through a foundry that has a radiation-hard field oxide process.

An advanced version of the test circuit that includes a 4 Kbit RAM which is expected to enhance the probability of detecting SEUs is under development. Once the devices are fabricated, they will be irradiated on the ground with both gamma rays and heavy ions. These test results will be compared to the results obtained from space.

TECHNICAL CONTACT: Martin Buehler, JPL, (818) 354-4368

CMOS-BULK TEST CHIP FOR CRRES

OBJECTIVES: TO OBSERVE THE EFFECTS OF NATURAL RADIATION ON TEST CIRCUITS, TO CORRELATE THE RESULTS WITH GROUND TESTS, AND TO DEVELOP EFFECTIVE MODELS

CMOS RAM:

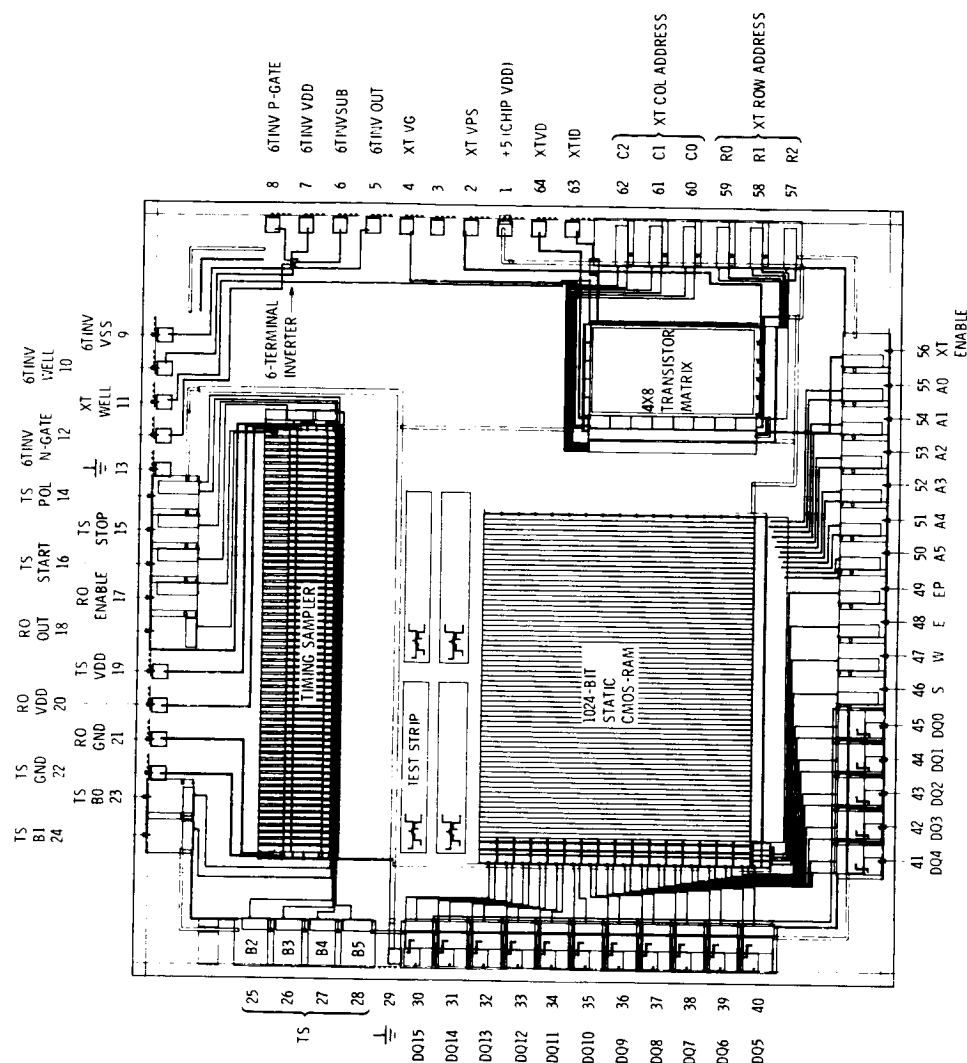
SEU STUDIES

TRANSISTOR MATRIX:

SPIICE PARAMETERS

TIMING SAMPLER:

PROPAGATION DELAY



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SOLID-STATE DEVICE RESEARCH

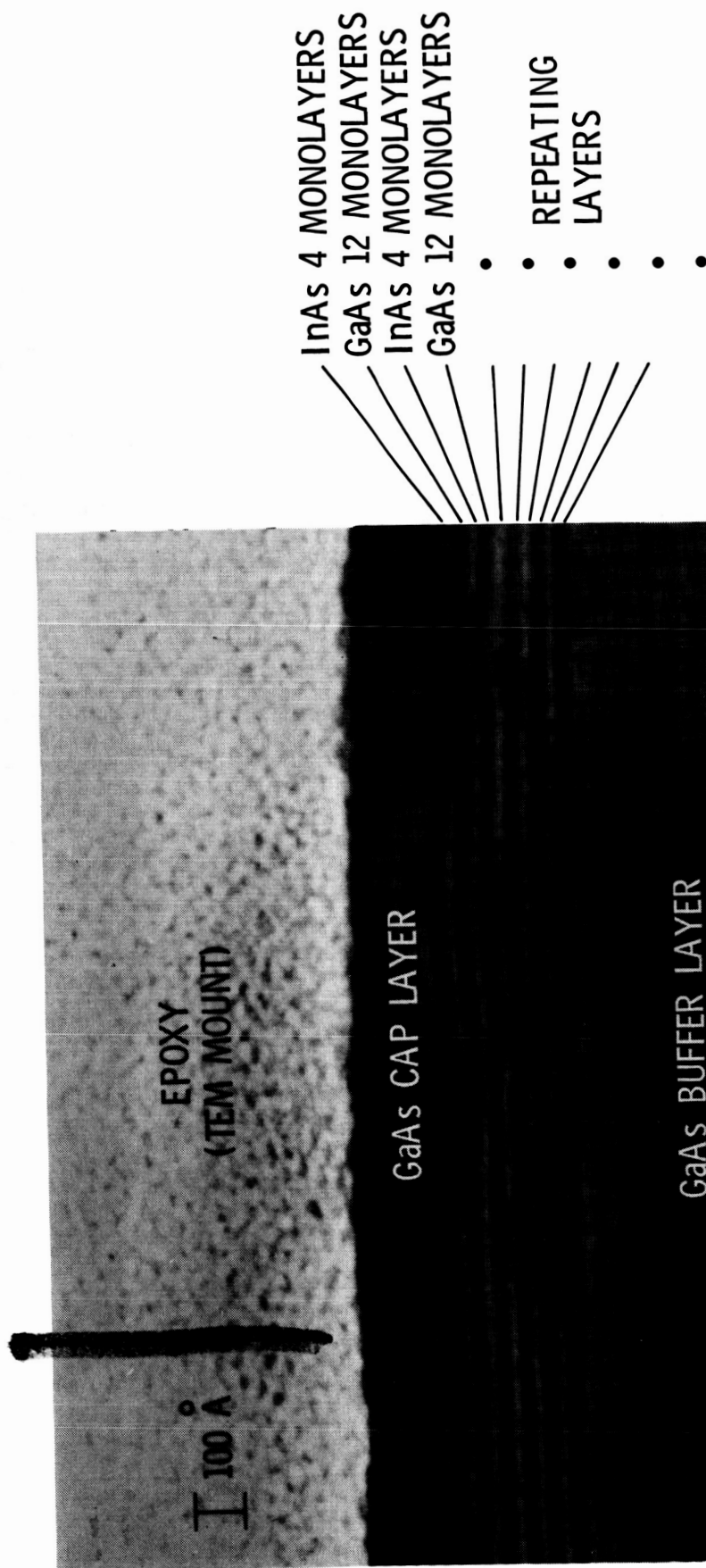
JPL's research on advancing techniques in Molecular Beam Epitaxy (MBE) is resulting in the development of new materials for optoelectronics. A major milestone was achieved this year in applying Reflection High Energy Electron Diffraction (RHEED) Intensity Oscillations as a major in situ tool for MBE. The RHEED technique looks at the diffraction pattern from electrons grazing the outer surface of a crystal. As growth on the outer surface of a crystal is observed with the RHEED technique, it undergoes a complete period of oscillation with each monolayer of growth. This allows observation of the kinetics of growth and morphology of the surface which allows control of the crystal growth to the monolayer level.

The RHEED technique was demonstrated in the growth of the first InAs/GaAs strained-layer superlattices. The precise indirect information provided by the RHEED technique is a required tool to grow the superlattice materials. In the InAs/GaAs material, the difference in atomic band lengths creates a strained layer where the atomic bands are not at normal angles. In order to stabilize the strained layer, another layer of GaAs is placed over the InAs layer which locks the strain into a very small (4 monolayer) area. Alternating layers creates a totally new material with different band characteristics and properties. This demonstration of the RHEED technique on MBE growth opens up development of a new class of materials that can be applied to optoelectronics.


JPL also developed a revolutionary MBE sample preparation technology using chemical methods to clean samples. Sample preparation is critical to successful MBE crystal growth. In addition, JPL demonstrated new noninvasive profiling techniques by using a XeF₂ laser for back-etching on silicon to investigate AR/SiO₂ and silicon nitride/SiO₂ interfaces. This XeF₂ laser etching technique allows the back surface to be removed, thus stopping at the real interface. Observations from the back side have opened up a whole new dimension of information.

TECHNICAL CONTACT: Joseph Maserjian, JPL, (818) 354-2259

CROSS-SECTIONAL TEM OF InAs/GaAs STRAINED LAYER SUPERLATTICE GROWN BY MBE



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